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THESIS

A Specification and Analysis of the  
IEEE Token Ring Protocol

by

Carl A. Raiche

June 1989

Thesis Advisor:

G. M. Lundy

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In this thesis *systems of communicating machines* is used to specify and analyze the IEEE token ring protocol. The specification makes several simplifying assumptions about the protocol in order to make the analysis manageable. These simplifications include limiting the network to two machines and shortening the frame and token formats to reduce the number of transmissions on the network. This thesis exercises the resulting specification to both verify that the protocol won't fail and that the specification is correct. The type of analysis used in this thesis is called a reachability analysis or a system state analysis.

This specification and analysis of the IEEE token ring protocol proves the protocol won't fail for a two machine network. This thesis also proves that the specification of the protocol is correct.

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**A Specification and Analysis of the IEEE Token Ring Protocol**

by

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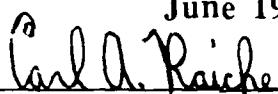
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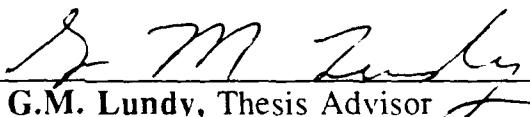
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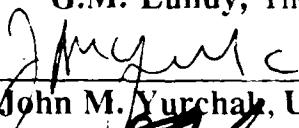
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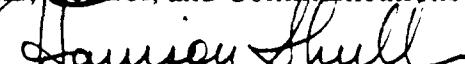
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## ABSTRACT

Computer communications are becoming increasingly important in the command, control and communications community. Using models to verify that the communication protocols used by these computers function properly is a time and effort saving device. A model called *systems of communicating machines* combines two types of models, finite state machines and programming language models.

In this thesis *systems of communicating machines* is used to specify and analyze the IEEE token ring protocol. The specification makes several simplifying assumptions about the protocol in order to make the analysis manageable. These simplifications include limiting the network to two machines and shortening the frame and token formats to reduce the number of transmissions on the network. This thesis exercises the resulting specification to both verify that the protocol won't fail and that the specification is correct. The type of analysis used in this thesis is called a reachability analysis or a system state analysis.

This specification and analysis of the IEEE token ring protocol proves the protocol won't fail for a two machine network. This thesis also proves that the specification of the protocol is correct.

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## I. INTRODUCTION

### A. FORMAL MODELING OF PROTOCOLS

A protocol is a set of rules and procedures used by different computers to communicate with each other. The protocols are implemented on the computers in a network as a set of common software. The purpose of a protocol is to establish a common set of rules and procedures to allow different computers to communicate. Protocols are designed in layers, with the bottom layer being the interface with the communications medium and the top layer being the user application. The number of layers in between depends on the design of a particular system and which standard (if any) it follows.

Each layer of a communications protocol is designed to accomplish specific tasks. These tasks range from transmitting bits on the communication medium and reading bits from the medium to breaking files destined for transfer into packets and formatting those packets into frames that will be recognizable to the receiving machine. The design and implementation of a large protocol suite can be a very complicated task; it is not always easy to understand how all the pieces fit together. This complexity makes the testing and verification of a new protocol difficult. Testing a new protocol design can also be very expensive; not only is computer time a valuable resource, but many potential failures can take days to occur.

Due to the complexity and expense of testing new protocols, systems designers turned to modeling the software to find potential problems. Many

methods for modeling computer networks have been developed: Petri nets, finite state machines, programming languages and hybrid models. Analysts use one or more of these models to specify a network as completely as possible and then run the model to test for possible system failures. These failures fall into two general categories: safety errors and progress errors. A safety error occurs when the protocol fails and communication ceases. Examples of safety errors include deadlock (a system state from which there is no exit) and livelock (an infinite loop of a small number of system states). A progress error occurs when one or more stations in the network is unable to participate in the communication activity. An example of a progress error is starvation (where one or more stations in the network never get a chance to transmit information). These models can help identify these potential failure conditions. They can also be used to prove the functional correctness of a particular protocol, assuming the model is accurate. For these reasons, much time and research effort has gone into the search for new, easier to use models.

## B. THE TOKEN RING PROTOCOL

A local area network (LAN) is designed to connect computers in a small geographic area, such as an office, building, or several buildings. These networks typically use microcomputers as workstations to share a minicomputer or mainframe among many users. The microcomputers also stand alone and enable their users to perform other computing functions without tying up the main computer. A typical use would be to run user applications requiring a lot of computational power and speed on the mainframe computer and use the microcomputers for electronic mail,

running programs remotely on the mainframe, etc. LANs also allow the users to share other expensive resources, such as a graphics printer.

The token ring network is a LAN. The computers on the network are connected serially in a ring configuration. Each computer has an upstream neighbor and a downstream neighbor. (See Figure 1). Data flows around the ring in one direction only. A computer receives data from its upstream neighbor and forwards data to its downstream neighbor. At any

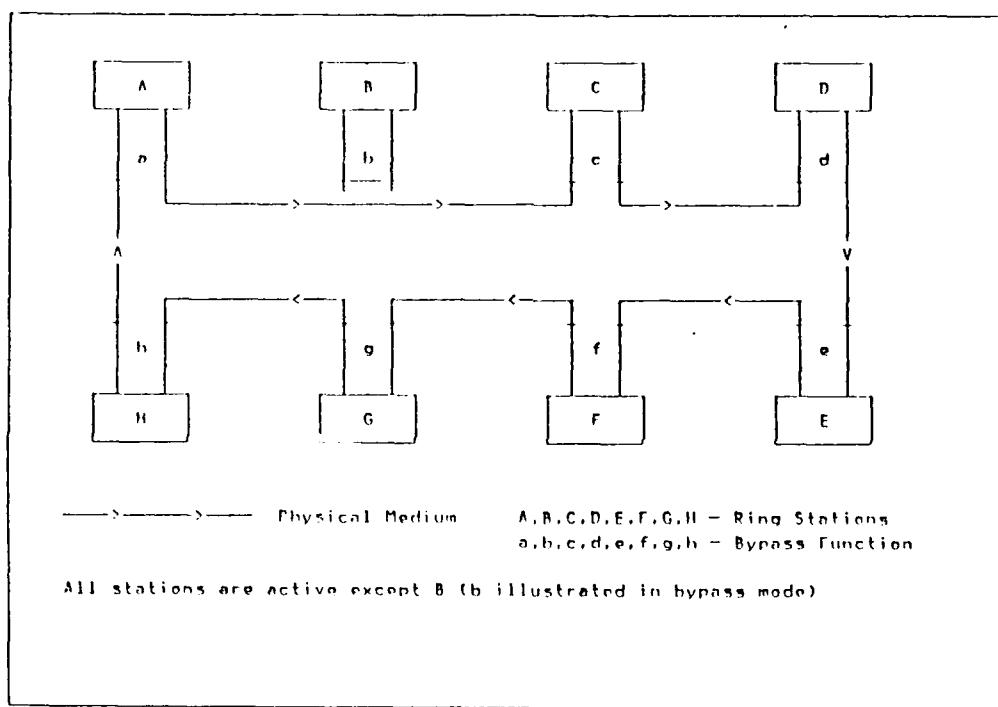


Figure 1: Token Ring Configuration

one time, only one computer is transmitting new data on the ring. All other computers are only repeating the transmitted data (and some are copying the data into buffers as they repeat it on the ring).

A unique pattern of bits, called a token, is continuously circulated on the ring. When a station wants to transmit, it must wait until it gets the token.

When it gets the token, it removes the token from the ring (so no one else can transmit) and transmits its data. Every station on the ring has a timer to prevent it from holding the token too long (and thus monopolizing the ring). When a station has completed transmitting, it waits for the message to return and then removes it. The station then generates and transmits a new token on the ring. In this manner, the token propagates around the ring and every station gets a chance to transmit eventually.

In 1985, the Institute of Electrical and Electronic Engineers (IEEE) and the American National Standards Institute (ANSI) issued the 802 group of standards. These standards defined the requirements for three types of LANs: the Carrier Sense Multiple Access with Collision Detect (CSMA/CD), the token passing bus, and the token ring. The purpose of these standards is to ensure uniformity among various LANs of the same type and allow users to buy equipment from different vendors and know it will follow the rules. These standards will also make it possible to connect different networks of the same type with a minimum amount of effort. The standard for the physical and medium access control layers of the token ring network, which is the basis for this thesis, is ANSI/IEEE Standard 802.5-1985.

### C. SYSTEMS OF COMMUNICATING MACHINES

One model used to specify and analyze communication protocols is called *systems of communicating machines*. This model has been used to specify several types of network protocols, such as CSMA/CD, High-Level Data Link Control (HDLC) and various routing protocols. It also has been used to specify a simplified version of the token ring protocol. Section II contains a detailed description of this model and the simplifying assumptions that were used to apply it to the token ring network.

*Systems of communicating machines* uses a combination of finite state machines and variables to model the token ring protocol. Each communicating machine is in one of several possible states and has local variables. In any particular state, one or more actions is possible. These actions may or may not lead to a state transition, and they may or may not change the values of some variables. Which actions are allowed depends on the values of the local and global variables and the current state of the communicating machine. All transitions and actions are instantaneous; once a transition is enabled, it may occur at any time. Communication between machines is accomplished through shared variables. Machines read and write these shared variables to communicate. Each communicating machine will have its own local state; the set of all local states in a network is either a system or a global state.

## II. THE SYSTEMS OF COMMUNICATING MACHINES MODEL

This chapter formally defines the *systems of communicating machines* model used to specify communication protocols. The first two sections of this chapter briefly describe the two modeling techniques, finite state machines and programming language models, which form the basis for the *systems of communicating machines* model. The third section gives the formal definition of the general model; the adaptation of this model used to specify the token ring protocol will be described in Chapter IV.

### A. COMMUNICATING FINITE STATE MACHINES

One method of modelling communication protocols is with communicating finite state machines. In this model, each process is modelled as a finite state machine and implicit queues are used for communication. Global states are used to define every possible condition of the network. A global state consists of the state of every process in the network and the contents of the queues. Transitions are enabled by various combinations of the contents of the queues, and thus machines in the network transition from state to state, possibly changing the contents of the queues when they transition.

Communicating finite state machines are primarily used to perform a reachability analysis. This analysis consists of exercising the model until every possible state has been generated from the starting state. This type

of analysis is useful for predicting deadlocks in the network and documenting the events leading to a deadlock.

The chief disadvantage of using communicating finite state machines for this analysis is the so-called "state explosion". Even if the queue lengths are finite (which is not required in the pure finite state machine model), modern protocols are so complex that the number of states generated with this model can be unmanageable. [Ref. 1]

## B. PROGRAMMING LANGUAGE MODELS

Programming language models of communication protocols have the advantage of being more flexible and robust than finite state machines. However, programming language models are also much more complex than finite state machines. Several programming languages have been developed or adapted for the purpose of modelling protocols. These languages include CSP, Ada, and LOTOS. While each language has features to aid in this analysis, the programming task can be very formidable if the protocol to be modelled is large and complex. [Ref. 1]

## C. SYSTEMS OF COMMUNICATING MACHINES

The systems of communicating machines model is an attempt to combine the best features of the finite state machine model with some features from the programming language model. The resulting model uses finite state machines, but it uses local variables to reduce the number of machine states. It also uses shared variables instead of queues for communicating.

The following formal definition of *systems of communicating machines* is quoted from [Ref. 2] and is reprinted here for the reader's convenience.

A *system of communicating machines* is an ordered pair  
 $C = (M, V)$ , where

$$M = \{m_1, m_2, \dots, m_n\}$$

is a finite set of machines, and

$$V = \{v_1, v_2, \dots, v_k\}$$

is a finite set of *shared variables*, with two designated subsets  $R_i$  and  $W_i$  specified for each machine  $m_i$ . The subset  $R_i$  of  $V$  is called the set of *read access variables* for machine  $m_i$ , and the subset  $W_i$  the set of *write access variables* for  $m_i$ .

Each machine  $m_i \in M$  is defined by a tuple  $(S_i, s, L_i, N_i, \tau_i)$ , where

- (1)  $S_i$  is a finite set of states;
- (2)  $s \in S_i$  is a designated state called the *initial state* of  $m_i$ ;
- (3)  $L_i$  is a finite set of *local variables*;
- (4)  $N_i$  is a finite set of names, each of which is associated with a unique pair  $(p, a)$ , where  $p$  is a predicate on the variables of  $L_i \cup R_i$ , and  $a$  is an *action* on the variables of  $L_i \cup R_i \cup W_i$ . Specifically, an action is a partial function

$$a: L_i \times R_i \dashrightarrow L_i \times W_i$$

from the values contained in the local variables and read access variables to the values of the local variables and write access variables.

- (5)  $\tau_i: S_i \times N_i \dashrightarrow S_i$  is a transition function, which is a partial function from the states and names of  $m_i$  to the states of  $m_i$ .

Machines model the entities, which in a protocol system are processes and channels. The shared variables are the means of communication between the machines. Intuitively,  $R_i$  and  $W_i$  are the subsets of  $V$  to which  $m_i$  has read and write access, respectively. A machine is allowed to make a transition from one state to another when the predicate associated with the name for that transition is true. Upon taking the transition, the action associated with that name is executed. The action changes the values of local and/or shared variables, thus allowing other predicates to become true.

The set  $L_i$  of local variables specifies a name and a range for each. The range must be a finite or countable set of values.

A *system state tuple* is a tuple of all machine states. That is, if  $(M, V)$  is a system of  $n$  communicating machines, and  $s_i$ , for  $1 \leq i \leq n$ , is the state of machine  $m_i$ , then the  $n$ -tuple  $(s_1, s_2, \dots, s_n)$  is the system state tuple of  $(M, V)$ . A *system state* is a system state tuple, plus the outgoing transitions which are enabled. That is, two system states are *equivalent* if every machine is in the same state, and the same outgoing transitions are enabled. The *initial system state* is the system state such that every machine is in its initial state, and the outgoing transitions are the same as in the initial global state.

The *global state* of a system consists of the system state, plus the values of all variables, both local and shared. It may be written as a larger tuple, combining the system state with the values of the variables. The *initial global state* is the initial system state, with the additional

requirement that all variables have their initial values. A global state corresponds to a system state if every machine is in the same state, and the same outgoing transitions are enabled. That is, a global state consists of a tuple of machine states, plus the values of all variables. A system state with the same tuple of machine states as the global state and the same enabled outgoing transitions is the corresponding system state.

Let  $\tau(s_i, n) = s_2$  be a transition which is defined on machine  $m_i$ . Transition  $\tau$  is enabled if the enabling predicate  $p$ , associated with name  $n$ , is true. Transition  $\tau$  may be executed whenever  $m_i$  is in state  $s_i$  and the predicate  $p$  is true (enabled). The execution of  $\tau$  is an atomic action, in which both the state change and the action  $a$  associated with  $n$  occur simultaneously.

Note that if the values of all variables are restricted to some finite range, then the model can theoretically be reduced to a simple finite state machine. Otherwise, an infinite number of global states are possible. However, even if the number of global states is infinite, the number of system states is finite, because of the finiteness of each machine. This may allow a reachability analysis on the system states, when a reachability analysis on the global states is infinite. Even when the values of all variables are of a finite range, the number of global states in the equivalent FSM system may be so large as to be intractable. [Ref. 2]

### III. THE IEEE TOKEN RING PROTOCOL

This chapter gives a brief overview of how a token ring LAN operates. The discussion is based on [Ref. 3] and therefore does not pertain to any particular implementation of the token ring protocol. Section A explains the physical layout of the network. Section B describes the formats of the frames and tokens that are circulated on the ring. Section C concludes this chapter with a description of how the token ring operates. For a more detailed explanation of the token ring protocol, see [Ref. 3].

#### A. TOPOLOGY

A token ring LAN is configured in a ring. Transmission is point to point, in one direction only. Most token rings use centrally located switching centers to accomplish the ring connections, and each station on the ring has its own cable connection to the switching center. When a particular station wants to connect to the ring, it sends a signal to the switching center. The switching center activates a relay that inserts the station into the ring; as long as the signal from the station is present, the relay remains energized and the station is connected to the ring. When an error is detected by either the switching center itself or the station, the relay is de-energized and the station is placed in the bypass mode. This scheme is very flexible; as long as there are connections available in the switching center, new stations can be added to the ring. The switching centers can also be connected to each other, allowing more room for expansion. The maximum size of a token ring

network is 250 stations, which is determined by timing and data rate considerations beyond the scope of this thesis.

## B. FORMATS

The token ring network uses a form of encoding known as differential Manchester. This encoding scheme allows timing information to be implicit in the data signal. It also allows two symbols to be defined which are not data symbols. These unique symbols, called J and K, are used in both the token and the frame starting and ending delimiters. If these unique symbols occur anywhere else in a frame, an error has occurred and the network accomplishes recovery procedures.

The token format is

[SD, AC, ED].

The frame format is

[SD, AC, FC, DA, SA, INFO, FCS, ED, FS].

SD is the starting delimiter and consists of J, K, and 0 symbols. AC is the access control field. A token bit in this field lets a receiving station know if it is processing a token or a frame; if it is a token, the receiving station may change the token bit to denote a token and begin transmitting its messages. The ED field is the ending delimiter and consists of J, K, and 1 symbols. The FC field in a frame is the frame control field and identifies the type of frame. The DA and SA fields are the destination and source addresses for this frame. The INFO field is the information field and is optional; i.e., a control frame does not need to contain an information field, but a data message will obviously contain information. The FCS field is the frame check sequence used for error detection. The FS field is the frame status field used by the receiver to acknowledge reception of a message.

For a more detailed explanation of these fields and their formats, see [Ref. 3].

### C. OPERATION

When a station on the ring wants to transmit a frame, it must first seize the token. When the station detects a usable token, i.e., a token with a priority that is equal to or lower than the priority of the frame the station wants to transmit, it sets the token bit to indicate a frame is next. Setting the token bit changes the token to a frame; the station has now "seized" the token. Now no other station can transmit new information onto the ring. The station proceeds to transmit its frame(s) until it is done or its maximum allowable time to hold the token expires (this time limit is determined by the network managers). The station then transmits an end-of-frame sequence and transmits fill (all zeroes) while it waits for the last frame transmitted to go full cycle and return. When this last frame is received, the station generates a new token and transmits it on the ring, allowing the next station an opportunity to transmit.

Every station is responsible for removing all messages it originates from the ring. This is necessary to ensure old frames do not circulate forever on the ring. While a station is waiting for its last transmitted frame to return, it is also stripping all its previous messages from the ring and replacing them with fill. The last field in a frame is used by the destination to acknowledge receipt of a frame. Two bits are used to indicate whether a station recognized its own address in the frame header and whether or not that station copied the frame into its buffers. These bits let the sending station know the result of its transmission.

On every token ring, one station assumes the role of active monitor; every other station on the ring is automatically a standby monitor. The active monitor is responsible for maintaining the ring in proper operating condition. It checks and corrects the signal timing to keep all stations synchronized. The active monitor checks to see that a token is always present on the ring. It monitors frames that pass to make sure they are new, not leftover frames that some station didn't remove. The active monitor also lets the other stations on the ring know that an active monitor is present by broadcasting a special control frame periodically. The active monitor uses timers to monitor these conditions; the timers are reset when certain conditions are met (such as a valid token going by). If an error is detected, the active monitor takes corrective actions. Every station on the ring that is not the active monitor is a standby monitor. If a standby monitor believes there is no active monitor present on the ring (because of the absence of the control frames), it will assume the role of active monitor. In this way, the token ring network is self-monitoring. For a more detailed description of the active monitor and its functions, see [Ref. 3].

## IV. SPECIFICATION OF THE TOKEN RING PROTOCOL

This chapter explains how *systems of communicating machines* can be used to specify and analyze the token ring protocol that is stated in [Ref. 3]. The general model is explained in Chapter II of this thesis; this chapter describes the specific adaptation of the model to specify the token ring protocol. Section A explains the assumptions used to simplify the protocol to make the model more manageable. Section B describes the formats of the tokens and frames which are transmitted by the stations in the model. Section C explains how the model is structured and how it works. The explanation includes a picture of the finite state machine part of the model, a description of the local and shared variables used by the communicating machines, and a transition name/action table to describe the various states and transitions between them.

### A. SIMPLIFICATIONS OF THE PROTOCOL

The model *systems of communicating machines* can be used to model the token ring protocol. In [Ref. 2], this model has been adapted to specify the token ring protocol. In order to keep the specification down to a reasonable size, several simplifications were made to the protocol. These simplifications were: (from [Ref.2])

1. No attempt is made to model the timing. It is assumed that transitions which are enabled will occur, eventually.

2. The input and output buffers (that is, the shared variables) of the entire network have the capacity to hold the largest frame transmitted on the ring. This means that when a station transmits a frame, it may transmit the entire message before checking its input buffers for the first part of the message.

3. Only one frame is transmitted before giving up the token. In the IEEE standard, a station may send as many frames as it can before the expiration of THT, the token holding timer. For purposes of brevity, in this section the limit is one message.

4. No errors in transmission. In the standard, much of the complexity of the protocol goes into handling errors.

5. All messages have equal priority. The standard protocol allows eight different priority levels, with an elaborate procedure for raising and lowering them.

6. No active or standby monitors. In the standard token ring, every station contains a monitor for various error checking. [Ref. 2]

Most of these simplifying assumptions could be relaxed, if a more realistic model is desired. However, none of these assumptions significantly changes the function of the protocol and the model is easier to analyze using them.

## B. MESSAGES AND FORMATS

In IEEE Standard 802.5-1985, four different types of units are transmitted on the ring: binary 0, binary 1, non-data symbol J and non-data symbol K. In the model used to specify the token ring protocol, the units transmitted on the ring are characters. This means that each station on the ring will transmit and receive a sequence of characters rather than

individual bits. The model uses two special characters, 'J' and 'K', to denote the beginning and end of a message, respectively. These special characters will not appear in the middle of a message. Two types of messages will be transmitted in this model: the token and the frame. The token shall have the format

[J, T, K]

and the frame shall have the format

[J, F, DA, SA, INFO, K, C],

where the DA and SA fields are both integers indicating the destination and source addresses of the frame, INFO is the data being transmitted (and thus will be a sequence of characters generated by a higher level protocol), and the C field is one bit. The C bit is the "frame copied" bit and lets the sender know whether or not the INFO was copied by the destination station. [Ref. 2]

The first character of any message is a J, followed by either a T or an F, indicating whether the message is a token or a frame. If the message is a token, the next character is a K, ending the message. If the message is a frame, the next two characters are integers indicating the destination and sending stations, followed by a sequence of characters which are the data being transmitted. The message ends with a K and the C bit. The receiver uses the C bit to indicate reception of the message to the sender. [Ref. 2]

### C. PROTOCOL SPECIFICATION

To specify the token ring protocol, a state diagram, an action table and a picture of the shared and local variables are used. Figure 2 depicts the state machine diagram of the model. Table 1 contains the action table, and Figure 3 shows the shared and local variables. Table 2 contains the

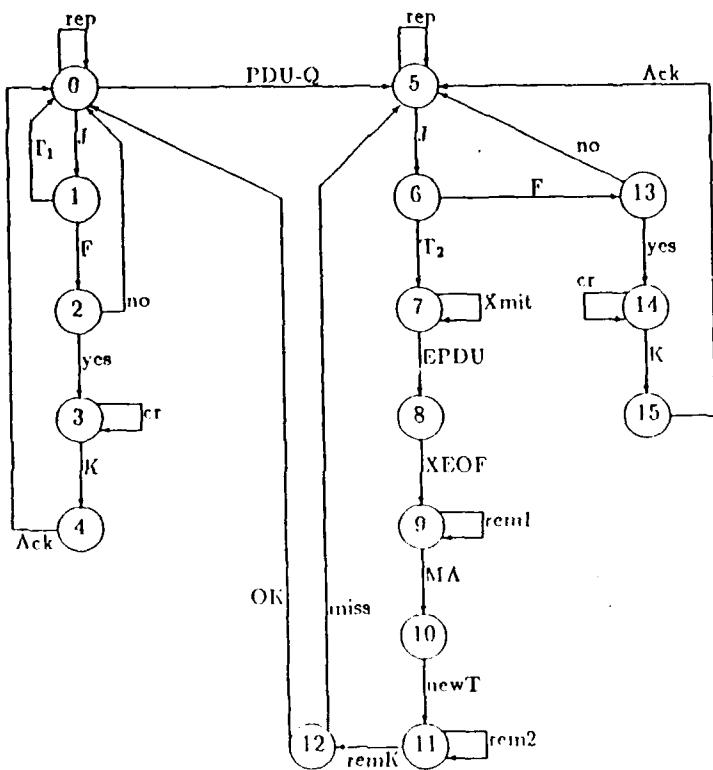


Figure 2: State Diagram for the Token Ring Protocol

transition names and their meanings; this table is not part of the specification but is included to aid the understanding of the transitions. [Ref. 2]

Each edge of the state diagram is labeled with a transition name. The enabling predicate and corresponding action which accompany the transition appear in Table 1, the action table. Figure 3 contains the shared and local variables associated with each station on the ring. The shared variables are inbuf and outbuf, while PDU and insgbuf are local to each station. The index variables (o, i, m, r, p) are also local variables. In the starting state (0 in

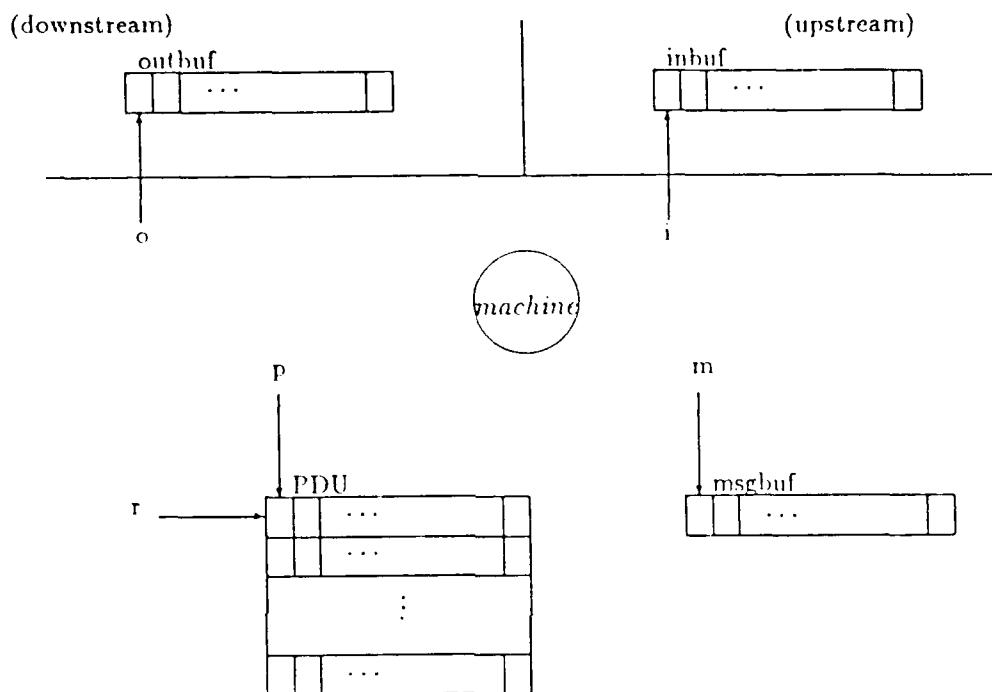
Figure 2), all buffer variables (inbuf, outbuf, PDU and msgbuf) are empty, with exactly one exception, and all index variables are equal to 1. The exception to the empty buffers is one shared variable on the ring contains the token, [J, T, K]. The local buffer variable PDU is used by the station to queue messages waiting for transmission on the ring. A PDU is a protocol data unit, the data block from the higher level protocol on the station. The msgbuf local variable is used to queue incoming messages from the ring until a higher level protocol is ready to accept them. [Ref. 2]

TABLE 1: ACTION TABLE FOR THE TOKEN RING PROTOCOL

transition	enabling predicate	action
<i>rep</i>	$inbuf(i) \in \{\emptyset, J\}$	<i>repeat</i>
$\tilde{PDU}\cdot Q$	$\tilde{PDU}(i) \neq \emptyset$	
<i>J</i>	$inbuf(i) = J$	<i>repeat</i>
<i>T<sub>1</sub></i>	$inbuf(i) = T$	<i>repeat</i>
<i>T</i>	$inbuf(i) = F$	<i>repeat</i>
<i>no</i>	$\neg inbuf(i) \in \{M, A, \emptyset\}$ $\vee msgbuf \neq \emptyset$	<i>repeat</i>
<i>yes</i>	$inbuf(i) = MA$ $\wedge msgbuf = \emptyset$	<i>repeat</i>
<i>er</i>	$inbuf(i) \neq K$	$msgbuf(m) \leftarrow inbuf(i); inc(m); repeat$
<i>K</i>	$inbuf(i) = K$	<i>repeat</i>
<i>Ack</i>	<i>true</i>	$outbuf(o) \leftarrow 1; inbuf(i) \leftarrow \emptyset; inc(o, i)$
<i>T<sub>2</sub></i>	$inbuf(i) = T$	$outbuf(o, o \oplus 1) \leftarrow (D, A, S, A); inc(o)$
<i>Xmit</i>	$\tilde{PDU}(i, p) \neq \emptyset$	$outbuf(o) \leftarrow \tilde{PDU}(i, p); inc(o, p)$
<i>LFIDU</i>	$\tilde{PDU}(i, p) = \emptyset$	$outbuf(o) \leftarrow K; inc(o); p \leftarrow 1$
<i>XEOF</i>		$outbuf(o) \leftarrow 0; inc(o);$
<i>rem1</i>	$inbuf(i) \neq (\emptyset \vee MA)$	$inbuf(i) \leftarrow \emptyset; inc(i)$
<i>MA</i>	$inbuf(i) = MA$	$inbuf(i) \leftarrow \emptyset; inc(i)$
<i>newT</i>	<i>true</i>	$outbuf(o, o \oplus 1, o \oplus 2) \leftarrow (J, T, K); o \leftarrow o \oplus 3$
<i>rem2</i>	$inbuf(i) \neq K$	$inbuf(i) \leftarrow \emptyset; inc(i)$
<i>remK</i>	$inbuf(i) = K$	$inbuf(i) \leftarrow \emptyset; inc(i)$
<i>miss</i>	$inbuf(i) = 0$	$inbuf(i) \leftarrow \emptyset; inc(i)$
<i>OK</i>	$inbuf(i) = 1$	$inbuf(i) \leftarrow \emptyset; inc(i), PDU(i) \leftarrow \emptyset, inc(i)$

The state diagram of Figure 2 for each machine on the ring can be viewed as two distinct parts. In the left side, states 0 - 4, the station has no PDU

Figure 3: Local and Shared Variables of the Token Ring



queued for transmission, while in the right side, states 5 - 15, the station has a PDU ready for transmission. A PDU is queued by a higher level protocol; the PDU is placed in the next available slot in the PDU buffer to await transmission. The enabling predicate for the *PDU-Q* transition from state 0 to state 5 reflects the result of this action by the higher level protocol. A station in state 0 is just repeating incoming characters to its downstream neighbor.

After a PDU is queued and the station has taken the transition to state 5, the station continues to repeat incoming characters until it can capture the

token and transmit the PDU. In both parts of the state diagram, the station must copy any messages addressed to this station into its msgbuf, unless the msgbuf is full. If the msgbuf is full, the higher level protocol has not yet read the last message received, and the station takes the *no* transition.

TABLE 2: MEANINGS OF THE TRANSITION NAMES

<i>transition</i>	<i>meaning</i>
<i>rep</i>	repeat character to the next station
<i>PDU-Q</i>	a PDU is queued for transmission
<i>J</i>	first character of a frame or token
<i>F</i>	second character of a frame
<i>no</i>	no, frame not sent to this station
<i>yes</i>	frame addressed to this station
<i>cr</i>	copy and repeat character to next station
<i>K</i>	ending delimiter for frame or token
<i>Ack</i>	acknowledgement of frame
<i>Xmit</i>	transmit frame
<i>EPDU</i>	end of protocol data unit
<i>XEOF</i>	transmit end of frame
<i>rem1</i>	remove 1st part of frame
<i>MA</i>	my address
<i>DA</i>	destination address
<i>SA</i>	source address
<i>newT</i>	transmit a new token
<i>rem2</i>	remove 2nd part of frame
<i>remK</i>	remove the K
<i>miss</i>	frame was not received successfully
<i>OK</i>	frame was received

This means the station does not receive the message; the sender will know because the C bit (the frame copied field) will not be set. [Ref. 2]

If a station has a PDU queued and it captures the token, the station transitions from state 5 through state 6 to state 7 and transmits the PDU. After transmitting the PDU, the station transitions to state 8 and then to state 9 by transmitting the 'K' character and the C bit (0). In state 9, the

station waits for the return of its message and strips it off the ring. When the station recognizes its own address in the SA field, it transitions to state 10 and transmits a new token on the ring. In state 11, the station removes the remainder of its message from the ring. In state 12, the station checks the frame copied bit, the C field. If C = 1, the destination station copied the frame and this station can clear the PDU buffer and return to state 0 via the *OK* transition. If C = 0, the destination station did not copy the frame, so this station returns to state 5 to retransmit the PDU (after recapturing the token, of course). [Ref. 2]

In the predicate-action table, Table 1, the action *repeat* is the basic act of retransmitting (repeating) the incoming character to the downstream station; it consists of the three statements

outbuf(0)  $\leftarrow$  inbuf(1); inbuf(1)  $\leftarrow$  0; inc(0, 1).

Increment (*inc*) adds one to each of its arguments using modulo arithmetic to simulate a circular counter (i.e., if an argument is at its maximum value, it is reset to its minimum value when it is incremented). [Ref. 2]

## V. ANALYSIS OF THE TOKEN RING PROTOCOL

This chapter explains the results of using the specification described in Chapter IV to analyze the token ring protocol. Section A gives the background for the analysis by explaining what a reachability analysis is and what the main problems associated with this type of analysis are. Section B explains the secondary goal of this type of analysis: verifying the model. Section B also describes the errors discovered in the specification of the token ring protocol. Section C describes what the results of the analysis were. The table included in Section C contains the 630 states that were generated when the model was run.

### A. TYPE OF ANALYSIS

As stated in Chapter II, a system state for the *Systems of Communicating Machines* model is a tuple consisting of the state of every machine in the network, plus the enabled outgoing transitions for each machine. A global state for this model is a tuple consisting of the state of every machine plus the values of all its variables, both local and shared. It is possible for one system state to correspond to several global states; that is, two system state tuples may be identical except for having different outgoing transitions enabled and therefore having different values in one or more variables.

One method of protocol analysis is called reachability analysis. Once a specification of the protocol has been developed, it can be run (either

manually or on a computer) until all the possible system states have been generated, or reached. These states can then be studied to detect possible protocol failures. A reachability analysis is mostly used to detect deadlock conditions. A deadlock exists when the system reaches a state from which there is no exit; all communication on the network comes to a halt. Other failure conditions that can be detected with a reachability analysis include starvation (one or more machines never get a chance to transmit on the network) and livelock (the network gets locked into a never-ending cycle of a small number of system states).

There are two main problems with this type of analysis. First of all, it is undecidable whether the analysis will ever terminate. This means that there may be an infinite number of possible states. Secondly, even if the analysis does terminate, there is for any nontrivial protocol a combinatorial explosion of states. This means that the number of states may be so large that even an automated analysis is impractical, taking days, weeks or years of computer time.

A reachability analysis was performed on the system states; this is called system state analysis. The analysis used an abbreviated form of the global states. The tuples consisted of the state of each machine and the values of its shared variables; local variables were not represented in order to keep the size of the tuples small. The network consisted of two machines; it is left to further research to expand the analysis to three or more machines. The results of this analysis are contained in Part C of this section. A total of 630 states were generated for this two-machine network, and no errors in the token ring protocol were discovered.

## B. VERIFYING THE MODEL

A secondary goal in performing a reachability analysis is to verify the proper operation of the model of the protocol. As the model is exercised and new system states are reached, the user can check to see that the transitions occur in a timely and logical (consistent with the actual protocol) manner. The model can be fine tuned to correct any deficiencies. It can also be modified to simplify the analysis or to bring its behavior closer to the actual protocol's functioning.

In performing a reachability analysis with *systems of communicating machines*, three errors were discovered in the token ring specification. Correcting these errors brought the specification's behavior in line with the protocol's function and also helped minimize the number of possible states.

In the original specification, the enabling predicate for the *no* transition (see Table 1) did not include  $\text{inbuf}(i) = 0$ . Not including this condition meant that a machine in states 2 or 13 could transition without having received the address of the frame. The intent of the *no* transition is to continue repeating if either the frame is addressed to someone else or this machine does not have room in its buffer for the frame. Adding the condition  $\text{inbuf}(i) = 0$  forces the machine to check the address and/or its buffers before transitioning.

The second error in the original specification involved the *Ack* transition. The original specification listed the transition as always enabled; a machine in states 4 or 15 could immediately transition. Problems arose if the sender had not taken the *XEOF* transition to state 9 yet. If the receiver sent an *Ack* and entered a repeat state, followed by the sender taking the *XEOF* transition and transmitting a 0, the receiver would repeat this 0 and an extra character would be in the queues. The *Ack*

transition was intended to remove this 0 from the system. Changing the enabling predicate for *Ack* to  $\text{inbuf}(1) = 0$  accomplishes this task.

The third correction to the original specification involved the *Xmit* transition. The *Xmit* transition's original action was:

$\text{outbuf}(o) \leftarrow \text{PDU}(r,p); \text{inc}(o,p)$ .

While this action is technically correct, it led to a larger number of states than necessary; i.e., every machine needed to take the *Xmit* transition three times in order to transmit a one-character PDU. Modifying the action to:

$\text{outbuf}(o) \leftarrow \text{PDU}(r,p); \text{inc}(o,p)$

and changing the action of the (preceding)  $T_2$  transition to:

$\text{outbuf}(o) \leftarrow F; \text{inbuf}(1) \leftarrow 0; \text{inc}(o,i);$

$\text{outbuf}(o, o+1) \leftarrow \text{DA, SA}; \text{inc}(o)$

simplifies this transition and allows the sender to transmit an entire PDU in one action.

### C. RESULTS OF THE ANALYSIS

Table 3 (in the appendix) contains a listing of all the states generated with a two-machine network using the *systems of communicating machines* model to specify a token ring network. The *num* column is a reference number for each abbreviated global state. The  $s_1$  column contains the state of machine 1, and similarly the  $s_2$  column contains the state of machine 2.

The  $\text{inbuf}_1$  column contains the contents of the *inbuf* shared variable for machine 1 (and therefore, for this two-machine network, the contents of the *outbuf* shared variable for machine 2); the  $\text{inbuf}_2$  column is the

contents of the inbuf shared variable for machine 2 and the outbuf shared variable for machine 1. The last column contains tuples made up of a transition name and a num reference number. The group of tuples represent all possible transitions from the current state; the num reference number for each transition directs the reader to the table entry for the new system state if that transition is taken. The superscripts on the transition name denote the number of the machine (1 or 2) which is taking that particular transition; superscripts were used rather than subscripts because some transition names contain subscripts already.

## VI. CONCLUSIONS AND RECOMMENDATIONS

This thesis used the *systems of communicating machines* model to specify the IEEE token ring protocol. The thesis then used this specification to analyze the protocol. The purpose of this analysis is both to verify the protocol functions properly and to verify the correctness of the specification.

The analysis in Section V proves that the token ring protocol will not fail in a two machine network. No states were generated from which there is no transition out; therefore, the protocol is deadlock-free. Also, since the token passed from one machine to the other with no problems, starvation does not exist in a network which properly installs the token ring standard. A close examination of the system states table shows that no loops exist, either. The network moves from state to state smoothly, and eventually returns to its starting state and starts the communication process all over again.

The analysis in Section V also serves to validate the model of the token ring protocol. Exhaustively exercising the model and generating every possible state proves the model functions properly. This model can be used to evaluate other token ring implementations to test for failure conditions and to test how well they conform to the IEEE standard.

This model makes several simplifying assumptions about the token ring protocol. Now that this version of the model has been verified, future versions may relieve one or more of those simplifying assumptions in order to more closely model the behavior of a token ring network. The model

could be modified to allow a station to transmit more than one frame at a time when it has the token. This change would require some sort of timing mechanism (such as another shared variable, called Clock) in order to model the token holding timer. Adding timing to the model would also make it more realistic. As the model now stands, one station can transmit several characters in a row without the other station reacting. In a real network, both stations would be transmitting alternately (actually, one station would be transmitting and one would be repeating). With timing in the model, the stations would have to take turns transmitting on the ring.

There are many ways to add to the model to make it more closely resemble the actual protocol. However, the analyst must be careful when adding complexity to the model. Adding too much detail can make the model too large and unwieldy to be a useful analytical tool. If the model yields too many possible system states, it will be too difficult to interpret the results of running the model.

Future research may want to add detail to the model and extend these results to a network with three or more machines. Extending the results to a network of  $n$  machines would prove the protocol won't fail under any conditions and would be very worthwhile.

## APPENDIX

TABLE 3: RESULTS OF THE ANALYSIS

<i>num</i>	<i>s</i> <sub>1</sub>	<i>inbuf</i> <sub>1</sub>	<i>s</i> <sub>2</sub>	<i>inbuf</i> <sub>2</sub>	<i>transitions</i>
0	0	<i>J, T, K</i>	0	—	(3, <i>J</i> <sup>1</sup> ), (2, <i>PDU</i> − <i>Q</i> <sup>2</sup> ), (1, <i>PDU</i> − <i>Q</i> <sup>1</sup> )
1	5	<i>J, T, K</i>	0	—	(46, <i>J</i> <sup>1</sup> ), (47, <i>PDU</i> − <i>Q</i> <sup>2</sup> )
2	0	<i>J, T, K</i>	5	—	(47, <i>PDU</i> − <i>Q</i> <sup>1</sup> ), (6, <i>J</i> <sup>1</sup> )
3	1	<i>T, K</i>	0	<i>J</i>	(1, <i>T</i> <sub>1</sub> <sup>1</sup> ), (5, <i>J</i> <sup>2</sup> ), (6, <i>PDU</i> − <i>Q</i> <sup>2</sup> )
4	0	<i>K</i>	0	<i>J, T</i>	(7, <i>rep</i> <sup>1</sup> ), (8, <i>PDU</i> − <i>Q</i> <sup>1</sup> ), (9, <i>PDU</i> − <i>Q</i> <sup>2</sup> ), (10, <i>J</i> <sup>2</sup> )
5	1	<i>T, K, J</i>	1	—	(10, <i>T</i> <sub>1</sub> <sup>1</sup> )
6	1	<i>T, K</i>	5	<i>J</i>	(9, <i>T</i> <sub>1</sub> <sup>1</sup> ), (11, <i>J</i> <sup>2</sup> )
7	0	—	0	<i>J, T, K</i>	(12, <i>PDU</i> − <i>Q</i> <sup>1</sup> ), (13, <i>PDU</i> − <i>Q</i> <sup>2</sup> ), (14, <i>J</i> <sup>2</sup> )
8	5	<i>K</i>	0	<i>J, T</i>	(12, <i>rep</i> <sup>1</sup> ), (15, <i>PDU</i> − <i>Q</i> <sup>2</sup> ), (16, <i>J</i> <sup>2</sup> )
9	0	<i>K</i>	5	<i>J, T</i>	(13, <i>rep</i> <sup>1</sup> ), (15, <i>PDU</i> − <i>Q</i> <sup>1</sup> ), (17, <i>J</i> <sup>2</sup> )
10	0	<i>K, J</i>	1	<i>T</i>	(14, <i>rep</i> <sup>1</sup> ), (16, <i>PDU</i> − <i>Q</i> <sup>1</sup> ), (18, <i>T</i> <sub>1</sub> <sup>2</sup> )
11	1	<i>T, K, J</i>	6	—	(17, <i>T</i> <sub>1</sub> <sup>1</sup> )
12	5	—	0	<i>J, T, K</i>	(19, <i>PDU</i> − <i>Q</i> <sup>2</sup> ), (20, <i>J</i> <sup>2</sup> )
13	0	—	5	<i>J, T, K</i>	(19, <i>PDU</i> − <i>Q</i> <sup>1</sup> ), (21, <i>J</i> <sup>2</sup> )
14	0	<i>J</i>	1	<i>T, K</i>	(20, <i>PDU</i> − <i>Q</i> <sup>1</sup> ), (22, <i>J</i> <sup>1</sup> ), (23, <i>T</i> <sub>1</sub> <sup>2</sup> )
15	5	<i>K</i>	5	<i>J, T</i>	(19, <i>rep</i> <sup>1</sup> ), (24, <i>J</i> <sup>2</sup> )
16	5	<i>K, J</i>	1	<i>T</i>	(20, <i>rep</i> <sup>1</sup> ), (25, <i>T</i> <sub>1</sub> <sup>2</sup> )
17	0	<i>K, J</i>	6	<i>T</i>	(21, <i>rep</i> <sup>1</sup> ), (24, <i>PDU</i> − <i>Q</i> <sup>1</sup> ), (26, <i>T</i> <sub>2</sub> <sup>1</sup> )
18	0	<i>K, J, T</i>	0	—	(23, <i>rep</i> <sup>1</sup> ), (25, <i>PDU</i> − <i>Q</i> <sup>1</sup> ), (27, <i>PDU</i> − <i>Q</i> <sup>2</sup> )
19	5	—	5	<i>J, T, K</i>	(28, <i>J</i> <sup>2</sup> )
20	5	<i>J</i>	1	<i>T, K</i>	(29, <i>J</i> <sup>1</sup> ), (30, <i>T</i> <sub>1</sub> <sup>1</sup> )
21	0	<i>J</i>	6	<i>T, K</i>	(28, <i>PDU</i> − <i>Q</i> <sup>1</sup> ), (31, <i>J</i> <sup>1</sup> ), (32, <i>T</i> <sub>2</sub> <sup>1</sup> )
22	1	—	1	<i>T, K, J</i>	(33, <i>T</i> <sub>1</sub> <sup>2</sup> )
23	0	<i>J, T</i>	0	<i>K</i>	(0, <i>rep</i> <sup>2</sup> ), (33, <i>J</i> <sup>1</sup> ), (34, <i>PDU</i> − <i>Q</i> <sup>2</sup> )
24	5	<i>K, J</i>	6	<i>T</i>	(28, <i>rep</i> <sup>1</sup> ), (35, <i>T</i> <sub>2</sub> <sup>1</sup> )
25	5	<i>K, J, T</i>	0	—	(30, <i>rep</i> <sup>1</sup> ), (36, <i>PDU</i> − <i>Q</i> <sup>2</sup> )
26	0	<i>K, J, F</i>	7	—	(32, <i>rep</i> <sup>1</sup> ), (35, <i>PDU</i> − <i>Q</i> <sup>1</sup> ), (38, <i>AMit</i> <sup>2</sup> )
27	0	<i>K, J, T</i>	5	—	(34, <i>rep</i> <sup>1</sup> ), (36, <i>PDU</i> − <i>Q</i> <sup>1</sup> )
28	5	<i>J</i>	6	<i>T, K</i>	(39, <i>J</i> <sup>1</sup> ), (40, <i>T</i> <sub>2</sub> <sup>1</sup> )
29	6	—	1	<i>T, K, J</i>	(41, <i>T</i> <sub>1</sub> <sup>2</sup> )
30	5	<i>J, T</i>	0	<i>K</i>	(1, <i>rep</i> <sup>2</sup> ), (11, <i>J</i> <sup>1</sup> ), (12, <i>PDU</i> − <i>Q</i> <sup>2</sup> )

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	transitions
31	1	—	6	$T, K, J$	$(43, T_2^1)$
32	0	$J, F$	7	$K$	$(40, PDU - Q^1), (43, J^1), (44, XMit^2)$
33	1	$T$	0	$K, J$	$(3, rep^2), (45, T_1^1), (46, PDU - Q^2)$
34	0	$J, T$	5	$K$	$(48, J^1), (42, PDU - Q^1), (2, rep^2)$
35	5	$K, J, F$	7	—	$(40, rep^1), (49, XMit^2)$
36	5	$K, J, T$	5	—	$(42, rep^1)$
38	0	$K, J, F, DA, SA, I$	7	—	$(49, PDU - Q^1), (41, rep^1), (50, EPDU^2)$
39	6	—	6	$T, K, J$	$(51, T_2^2)$
40	5	$J, F$	7	$K$	$(51, J^1), (52, XMit^2)$
41	6	$T$	0	$K, J$	$(53, T_2^1), (46, rep^2), (54, PDU - Q^2)$
42	5	$J, T$	5	$K$	$(54, J^1), (47, rep^2)$
43	1	$F$	7	$K, J$	$(55, F^1), (56, XMit^2)$
44	0	$J, F, DA, SA, I$	7	$K$	$(56, J^1), (52, PDU - Q^1), (57, EPDU^2)$
45	0	—	0	$K, J, T$	$(58, PDU - Q^1), (59, PDU - Q^2), (4, rep^2)$
46	6	$T, K$	0	$J$	$(60, T_2^1), (61, J^2), (62, PDU - Q^2)$
47	5	$J, T, K$	5	—	$(62, J^1)$
48	1	$T$	5	$K, J$	$(59, T_1^1), (6, rep^2)$
49	5	$K, J, F, DA, SA, I$	7	—	$(52, rep^1), (63, EPDU^2)$
50	0	$K, J, F, DA, SA, I, K$	8	—	$(57, rep^1), (63, PDU - Q^1), (64, XEOF^2)$
51	6	$F$	7	$K, J$	$(65, F^1), (66, XMit^2)$
52	5	$J, F, DA, SA, I$	7	$K$	$(66, J^1), (67, EPDU^2)$
53	7	—	0	$K, J, F$	$(68, XMit^1), (60, rep^2), (69, PDU - Q^2)$
54	6	$T$	5	$K, J$	$(69, T_2^1), (62, rep^2)$
55	2	—	7	$K, J, F$	$(70, XMit^2)$
56	1	$F, DA, SA, I$	7	$K, J$	$(70, F^1), (71, EPDU^2)$
57	0	$J, F, DA, SA, I, K$	8	$K$	$(71, J^1), (67, PDU - Q^1), (72, XEOF^2)$
58	5	—	0	$K, J, I$	$(8, rep^2), (73, PDU - Q^2)$
59	0	—	5	$K, J, T$	$(73, PDU - Q^1), (9, rep^2)$
60	7	$K$	0	$J, F$	$(74, XMit^1), (75, J^2), (76, PDU - Q^2)$

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	transitions
61	6	$T, K, J$	1	—	$(75, T_2^1)$
62	6	$T, K$	5	$J$	$(76, T_2^1), (77, J^2)$
63	5	$K, J, F, DA, SA, I, K$	8	—	$(67, rep^1), (78, XEOF^2)$
64	0	$K, J, F, DA, SA, I, K, 0$	9	—	$(72, rep^1), (78, PDU - Q^1)$
65	13	—	7	$K, J, F$	$(79, XMit^1)$
66	6	$F, DA, SA, I$	7	$K, J$	$(79, F^1), (80, EPDU^2)$
67	5	$J, F, DA, SA, I, K$	8	$K$	$(80, J^1), (81, XEOF^2)$
68	7	—	0	$K, J, F, DA, SA, I$	$(82, EPDU^1), (74, rep^2), (83, PDU - Q^2)$
69	7	—	5	$K, J, F$	$(83, XMit^1), (76, rep^2)$
70	2	$DA, SA, I$	7	$K, J, F$	$(84, yes^1), (85, no^1), (86, EPDU^2)$
71	1	$F, DA, SA, I, K$	8	$K, J$	$(86, F^1), (87, XEOF^2)$
72	0	$J, F, DA, SA, I, K, 0$	9	$K$	$(87, J^1), (81, PDU - Q^1), (88, rem1^2)$
73	5	—	5	$K, J, T$	$(15, rep^2)$
74	7	$K$	0	$J, F, DA, SA, I$	$(89, EPDU^1), (90, J^2), (91, PDU - Q^2)$
75	7	$K, J$	1	$F$	$(90, XMit^1), (92, F^2)$
76	7	$K$	5	$J, F$	$(91, XMit^1), (93, J^2)$
77	6	$T, K, J$	6	—	$(93, T_2^1)$
78	5	$K, J, F, DA, SA, I, K, 0$	9	—	$(81, rep^1)$
79	13	$DA, SA, I$	7	$K, J, F$	$(94, yes^1), (95, no^1), (96, EPDU^2)$
80	6	$F, DA, SA, I, K$	8	$K, J$	$(96, F^1), (97, XEOF^2)$
81	5	$J, F, DA, SA, I, K, 0$	9	$K$	$(97, J^1), (98, rem1^2)$
82	8	—	0	$K, J, F, DA, SA, I, K$	$(99, XEOF^1), (89, rep^2), (100, PDU - Q^2)$
83	7	—	5	$K, J, F, DA, SA, I$	$(100, EPDU^1), (91, rep^2)$

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	transitions
81	3	$SA, I$	7	$K, J, F, DA$	(101, $cr^1$ ), (102, $EPDU^2$ )
85	0	$SA, I$	7	$K, J, F, DA$	(103, $rep^1$ ), (95, $PDU - Q^1$ ), (101, $EPDU^2$ )
86	2	$DA, SA, I, K$	8	$K, J, F$	(102, $yes^1$ ), (101, $no^1$ ), (105, $XEOF^2$ )
87	1	$F, DA, SA, I, K, 0$	9	$K, J$	(105, $F^1$ ), (106, $rem^1$ )
88	0	$J, F, DA, SA, I, K, 0$	9	—	(106, $rep^1$ ), (98, $PDU - Q^1$ )
89	8	$K$	0	$J, F, DA, SA, I, K$	(107, $XEOF^1$ ), (108, $rep^2$ ), (109, $PDU - Q^2$ )
90	7	$K, J$	1	$F, DA, SA, I$	(108, $EPDU^1$ ), (110, $F^2$ )
91	7	$K$	5	$J, F, DA, SA, I$	(109, $EPDU^1$ ), (111, $J^2$ )
92	7	$K, J, F$	2	—	(110, $XMit^1$ )
93	7	$K, J$	6	$F$	(111, $XMit^1$ ), (112, $F^1$ )
94	11	$SA, I$	7	$K, J, F, DA$	(113, $cr^1$ ), (111, $EPDU^2$ )
95	5	$SA, I$	7	$K, J, F, DA$	(115, $rep^1$ ), (116, $EPDU^2$ )
96	13	$DA, SA, I, K$	8	$K, J, F$	(114, $yes^1$ ), (116, $no^1$ ), (117, $XEOF^2$ )
97	6	$F, DA, SA, I, K, 0$	9	$K, J$	(117, $F^1$ ), (118, $rem^1$ )
98	5	$J, F, DA, SA, I, K, 0$	9	—	(118, $J^1$ )
99	9	—	0	$K, J, F, DA, SA, I, K, 0$	(107, $rep^2$ ), (119, $PDU - Q^2$ )
100	8	—	5	$K, J, F, DA, SA, I, K$	(119, $XEOF^1$ ), (109, $rep^2$ )
101	3	$I$	7	$K, J, F, DA, SA$	(120, $cr^1$ ), (121, $EPDU^2$ )
102	3	$SA, I, K$	8	$K, J, F, DA$	(121, $cr^1$ ), (122, $XEOF^2$ )
103	0	$I$	7	$K, J, F, DA, SA$	(123, $rep^1$ ), (115, $PDU - Q^1$ ), (124, $EPDU^2$ )
104	0	$SA, I, K$	8	$K, J, F, DA$	(124, $rep^1$ ), (116, $PDU - Q^1$ ), (125, $XEOF^2$ )
105	2	$DA, SA, I, K, 0$	9	$K, J, F$	(122, $yes^1$ ), (125, $no^1$ ), (126, $rem^1$ )
106	1	$F, DA, SA, I, K, 0$	9	$J$	(126, $F^1$ ), (127, $rem^1$ )

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	transitions
107	9	$K$	0	$J, F, DA, SA, I, K, 0$	$(128, rem^1), (129, PDU - Q^2), (130, J^2)$
108	8	$K, J$	1	$F, DA, SA, I, K$	$(130, XEOF^1), (131, F^2)$
109	8	$K$	5	$J, F, DA, SA, I, K$	$(129, XEOF^1), (132, J^2)$
110	7	$K, J, F$	2	$DA, SA, I$	$(131, EPDU^1), (133, yes^2), (134, no^2)$
111	7	$K, J$	6	$F, DA, SA, I$	$(132, EPDU^1), (135, F^2)$
112	7	$K, J, F$	13	—	$(135, XMit^1)$
113	14	$I$	7	$K, J, F, DA, SA$	$(136, cr^1), (137, EPDU^2)$
114	14	$SA, I, K$	8	$K, J, F, DA$	$(137, cr^1), (138, XEOF^2)$
115	5	$I$	7	$K, J, F, DA, SA$	$(139, rep^1), (140, EPDU^2)$
116	5	$SA, I, K$	8	$K, J, F, DA$	$(140, rep^1), (141, XEOF^2)$
117	13	$DA, SA, I, K, 0$	9	$K, J, F$	$(138, yes^1), (141, no^1), (142, rem^1)$
118	6	$F, DA, SA, I, K, 0$	9	$J$	$(142, F^1), (143, rem^1)$
119	9	—	5	$K, J, F, DA, SA, I, K, 0$	$(129, rep^1)$
120	3	—	7	$K, J, F, DA, SA, I$	$(144, EPDU^2)$
121	3	$I, K$	8	$K, J, F, DA, SA$	$(144, cr^1), (145, XEOF^2)$
122	3	$SA, I, K, 0$	9	$K, J, F, DA$	$(145, cr^1), (146, rem^1)$
123	0	—	7	$K, J, F, DA, SA, I$	$(139, PDU - Q^1), (147, EPDU^2)$
124	0	$I, K$	8	$K, J, F, DA, SA$	$(147, rep^1), (140, PDU - Q^1), (148, XEOF^2)$
125	0	$SA, I, K, 0$	9	$K, J, F, DA$	$(148, rep^1), (141, PDU - Q^1), (149, rem^1)$
126	2	$DA, SA, I, K, 0$	9	$J, F$	$(146, yes^1), (149, no^1), (150, rem^1)$
127	1	$F, DA, SA, I, K, 0$	9	—	$(150, F^1)$
128	9	—	0	$J, F, DA, SA, I, K, 0$	$(151, J^2), (152, PDU - Q^1)$
129	9	$K$	5	$J, F, DA, SA, I, K, 0$	$(152, rem^1), (153, J^2)$
130	9	$K, J$	1	$F, DA, SA, I, K, 0$	$(151, rem^1), (151, F^2)$
131	8	$K, J, F$	2	$DA, SA, I, K$	$(151, XEOF^1), (155, yes^2), (156, no^2)$

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	transitions
132	8	$K, J$	6	$F, DA, SA, I, K$	(153, $XEOF^1$ ), (157, $F^2$ )
133	7	$K, J, F, DA$	3	$SA, I$	(155, $EPDU^1$ ), (158, $cr^2$ )
134	7	$K, J, F, DA$	0	$SA, I$	(156, $EPDU^1$ ), (159, $rep^2$ ), (160, $PDU - Q^2$ )
135	7	$K, J, F$	13	$DA, SA, I$	(157, $EPDU^1$ ), (161, $yes^2$ ), (160, $no^2$ )
136	14	—	7	$K, J, F, DA, SA, I$	(162, $EPDU^2$ )
137	14	$I, K$	8	$K, J, F, DA, SA$	(162, $cr^1$ ), (163, $XEOF^2$ )
138	14	$SA, I, K, 0$	9	$K, J, F, DA$	(163, $cr^1$ ), (164, $rem1^2$ )
139	5	—	7	$K, J, F, DA, SA, I$	(165, $EPDU^2$ )
140	5	$I, K$	8	$K, J, F, DA, SA$	(165, $rep^1$ ), (166, $XEOF^2$ )
141	5	$SA, I, K, 0$	9	$K, J, F, DA$	(166, $rep^1$ ), (167, $rem1^2$ )
142	13	$DA, SA, I, K, 0$	9	$J, F$	(161, $yes^1$ ), (167, $no^1$ ), (168, $rem1^2$ )
143	6	$F, DA, SA, I, K, 0$	9	—	(168, $F^1$ )
144	3	$K$	8	$K, J, F, DA, SA, I$	(169, $K^1$ ), (170, $XEOF^2$ )
145	3	$I, K, 0$	9	$K, J, F, DA, SA$	(170, $cr^1$ ), (171, $rem1^2$ )
146	3	$SA, I, K, 0$	9	$J, F, DA$	(171, $cr^1$ ), (172, $rem1^2$ )
147	0	$K$	8	$K, J, F, DA, SA, I$	(173, $rep^1$ ), (165, $PDU - Q^1$ ), • (174, $XEOF^2$ )
148	0	$I, K, 0$	9	$K, J, F, DA, SA$	(174, $rep^1$ ), (166, $PDU - Q^1$ ), (175, $rem1^2$ )
149	0	$SA, I, K, 0$	9	$J, F, DA$	(175, $rep^1$ ), (167, $PDU - Q^1$ ), (176, $rem1^2$ )
150	2	$DA, SA, I, K, 0$	9	$F$	(172, $yes^1$ ), (176, $no^1$ ), (177, $rem1^2$ )
151	9	$J$	1	$F, DA, SA, I, K, 0$	(178, $rem1^1$ ), (179, $F^2$ )
152	9	—	5	$J, F, DA, SA, I, K, 0$	(180, $J^2$ )
153	9	$K, J$	6	$F, DA, SA, I, K, 0$	(180, $rem1^1$ ), (181, $F^2$ )
154	9	$K, J, F$	2	$DA, SA, I, K, 0$	(179, $rem1^1$ ), (182, $yes^2$ ), (183, $no^2$ )
155	8	$K, J, F, DA$	3	$SA, I, K$	(182, $XEOF^1$ ), (181, $cr^2$ )
156	8	$K, J, F, DA$	0	$SA, I, K$	(183, $XEOF^1$ ), (185, $rep^2$ ), (186, $PDU - Q^2$ )

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	transitions
157	8	$K, J, F$	13	$DA, SA, I, K$	$(181, XEOF^1), (187, yes^2), (186, no^2)$
158	7	$K, J, F, DA, SA$	3	$I$	$(181, EPDU^1), (188, cr^2)$
159	7	$K, J, F, DA, SA$	0	$I$	$(185, EPDU^1), (189, rep^2), (190, PDU - Q^2)$
160	7	$K, J, F, DA$	5	$SA, I$	$(186, EPDU^1), (190, rep^2)$
161	7	$K, J, F, DA$	11	$SA, I$	$(187, EPDU^1), (191, cr^2)$
162	14	$K$	8	$K, J, F, DA, SA, I$	$(192, K^1), (193, XEOF^2)$
163	11	$I, K, 0$	9	$K, J, F, DA, SA$	$(193, cr^1), (194, rem1^2)$
164	11	$SA, I, K, 0$	9	$J, F, DA$	$(194, cr^1), (195, rem1^2)$
165	5	$K$	8	$K, J, F, DA, SA, I$	$(196, rep^1), (197, XEOF^2)$
166	5	$I, K, 0$	9	$K, J, F, DA, SA$	$(197, rep^1), (198, rem1^2)$
167	5	$SA, I, K, 0$	9	$J, F, DA$	$(198, rep^1), (199, rem1^2)$
168	13	$DA, SA, I, K, 0$	9	$F$	$(195, yes^1), (199, no^1), (200, rem1^2)$
169	4	—	8	$K, J, F, DA, SA, I, K$	$(202, XEOF^2)$
170	3	$K, 0$	9	$K, J, F, DA, SA, I$	$(202, K^1), (203, rem1^2)$
171	3	$I, K, 0$	9	$J, F, DA, SA$	$(203, cr^1), (204, rem1^2)$
172	3	$SA, I, K, 0$	9	$F, DA$	$(204, cr^1), (205, rem1^2)$
173	0	—	8	$K, J, F, DA, SA, I, K$	$(206, PDU - Q^1), (207, XEOF^2)$
174	0	$K, 0$	9	$K, J, F, DA, SA, I$	$(207, rep^1), (197, PDU - Q^1), (208, rem1^2)$
175	0	$I, K, 0$	9	$J, F, DA, SA$	$(208, rep^1), (198, PDU - Q^1), (209, rem1^2)$
176	0	$SA, I, K, 0$	9	$F, DA$	$(209, rep^1), (199, PDU - Q^1), (210, rem1^2)$
177	2	$DA, SA, I, K, 0$	9	—	$(205, yes^1), (210, no^1)$
178	9	—	1	$F, DA, SA, I, K, 0$	$(211, F^2)$
179	9	$J, F$	2	$DA, SA, I, K, 0$	$(211, rem1^1), (212, yes^2), (213, no^2)$
180	9	$J$	6	$F, DA, SA, I, K, 0$	$(214, rem1^1), (215, F^2)$

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	transitions
181	0	$K, J, F$	13	$DA, SA, I, K, 0$	$(215, rem1^1), (216, yes^2), (217, no^2)$
182	9	$K, J, F, DA$	3	$SA, I, K, 0$	$(212, rem1^1), (218, cr^2)$
183	9	$K, J, F, DA$	0	$SA, I, K, 0$	$(213, rem1^1), (217, PDU - Q^2), (219, rep^2)$
184	8	$K, J, F, DA, SA$	3	$I, K$	$(218, XEOF^1), (220, cr^2)$
185	8	$K, J, F, DA, SA$	0	$I, K$	$(219, XEOF^1), (221, rep^2), (222, PDU - Q^2)$
186	8	$K, J, F, DA$	5	$SA, I, K$	$(217, XEOF^1), (222, rep^2)$
187	8	$K, J, F, DA$	11	$SA, I, K$	$(216, XEOF^1), (223, cr^2)$
188	7	$K, J, F, DA, SA, I$	3	—	$(220, EPDU^1)$
189	7	$K, J, F, DA, SA, I$	0	—	$(221, EPDU^1), (221, PDU - Q^2)$
190	7	$K, J, F, DA, SA$	5	$I$	$(222, EPDU^1), (224, rep^2)$
191	7	$K, J, F, DA, SA$	11	$I$	$(223, EPDU^1), (225, cr^2)$
192	15	—	8	$K, J, F, DA, SA, I, K$	$(227, XEOF^2)$
193	14	$K, 0$	9	$K, J, F, DA, SA, I$	$(227, K^1), (228, rem1^2)$
194	14	$I, K, 0$	9	$J, F, DA, SA$	$(228, cr^1), (229, rem1^2)$
195	14	$SA, I, K, 0$	9	$F, DA$	$(229, cr^1), (230, rem1^2)$
196	5	—	8	$K, J, F, DA, SA, I, K$	$(231, XEOF^2)$
197	5	$K, 0$	9	$K, J, F, DA, SA, I$	$(231, rep^1), (232, rem1^2)$
198	5	$I, K, 0$	9	$J, F, DA, SA$	$(232, rep^1), (233, rem1^2)$
199	5	$SA, I, K, 0$	9	$F, DA$	$(233, rep^1), (234, rem1^2)$
200	13	$DA, SA, I, K, 0$	9	—	$(230, yes^1), (231, no^1)$
202	1	0	9	$K, J, F, DA, SA, I, K$	$(236, Ack^1), (237, rem1^2)$
203	3	$K, 0$	9	$J, F, DA, SA, I$	$(237, K^1), (238, rem1^2)$
204	3	$I, K, 0$	9	$J, DA, SA$	$(238, cr^1), (239, rem1^2)$
205	3	$SA, I, K, 0$	9	$DA$	$(239, cr^1), (240, rem1^2)$
206	5	—	8	$K, J, F, DA, SA, I, K$	$(231, XEOF^2)$
207	0	0	9	$K, J, F, DA, SA, I, K$	$(231, PDU - Q^1), (241, rep^1), (242, rem1^2)$

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	transitions
208	0	$K, 0$	9	$J, F, DA, SA, I$	(212, $rep^1$ ), (232, $PDU - Q^1$ ), (213, $rem1^2$ )
209	0	$I, K, 0$	9	$F, DA, SA$	(213, $rep^1$ ), (233, $PDU - Q^1$ ), (214, $rem1^2$ )
210	0	$SA, I, K, 0$	9	$DA$	(244, $rep^1$ ), (234, $PDU - Q^1$ ), (215, $rem1^2$ )
211	9	$F$	2	$DA, SA, I, K, 0$	(246, $rem1^1$ ), (247, $yes^2$ ), (248, $no^2$ )
212	9	$J, F, DA$	3	$SA, I, K, 0$	(247, $rem1^1$ ), (249, $cr^2$ )
213	9	$J, F, DA$	0	$SA, I, K, 0$	(248, $rem1^1$ ), (250, $PDU - Q^2$ ), (251, $rep^2$ )
214	9	$-$	6	$F, DA, SA, I, K, 0$	(252, $F^2$ )
215	9	$J, F$	13	$DA, SA, I, K, 0$	(252, $rem1^1$ ), (253, $yes^2$ ), (250, $no^2$ )
216	9	$K, J, F, DA$	11	$SA, I, K, 0$	(253, $rem1^1$ ), (251, $cr^2$ )
217	9	$K, J, F, DA$	5	$SA, I, K, 0$	(250, $rem1^1$ ), (255, $rep^2$ )
218	9	$K, J, F, DA, SA$	3	$I, K, 0$	(249, $rem1^1$ ), (256, $cr^2$ )
219	9	$K, J, F, DA, SA$	0	$I, K, 0$	(251, $rem1^1$ ), (255, $PDU - Q^2$ ), (257, $rep^2$ )
220	8	$K, J, F, DA, SA, I$	3	$K$	(256, $\Lambda EOF^1$ ), (258, $K^2$ )
221	8	$K, J, F, DA, SA, I$	0	$K$	(257, $\Lambda EOF^1$ ), (259, $PDU - Q^2$ ), (260, $rep^2$ )
222	8	$K, J, F, DA, SA$	5	$I, K$	(255, $\Lambda EOF^1$ ), (259, $rep^2$ )
223	8	$K, J, F, DA, SA$	11	$I, K$	(251, $\Lambda EOF^1$ ), (261, $cr^2$ )
224	7	$K, J, F, DA, SA, I$	5	$-$	(259, $EPDU^1$ )
225	7	$K, J, F, DA, SA, I$	11	$-$	(261, $EPDU^1$ )
226	15	$0$	9	$K, J, F, DA, SA, I, K$	(262, $Ack^1$ ), (263, $rem1^2$ )
228	14	$K, 0$	9	$J, F, DA, SA, I$	(263, $K^1$ ), (264, $rem1^2$ )
229	14	$I, K, 0$	9	$F, DA, SA$	(264, $cr^1$ ), (265, $rem1^2$ )
230	14	$SA, I, K, 0$	9	$DA$	(265, $cr^1$ ), (266, $rem1^2$ )

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	transitions
231	5	0	9	$K, J, F, DA, SA, I, K$	(267, $rep^1$ ), (268, $rem1^2$ )
232	5	$K, 0$	9	$J, F, DA, SA, I$	(268, $rep^1$ ), (269, $rem1^2$ )
233	5	$I, K, 0$	9	$F, DA, SA$	(269, $rep^1$ ), (270, $rem1^2$ )
234	5	$SA, I, K, 0$	9	$DA$	(270, $rep^1$ ), (271, $rem1^2$ )
236	0	—	9	$K, J, F, DA, SA, I, K, I$	(262, $PDU - Q^1$ ), (272, $rem1^2$ )
237	4	0	9	$J, F, DA, SA, I, K$	(272, $Ack^1$ ), (273, $rem1^2$ )
238	3	$K, 0$	9	$F, DA, SA, I$	(273, $K^1$ ), (274, $rem1^2$ )
239	3	$I, K, 0$	9	$DA, SA$	(274, $cr^1$ ), (275, $rem1^2$ )
240	3	$SA, I, K, 0$	9	—	(275, $cr^1$ )
241	0	—	9	$K, J, F, DA, SA, I, K, 0$	(267, $PDU - Q^1$ ), (276, $rem1^2$ )
242	0	0	9	$J, F, DA, SA, I, K$	(276, $rep^1$ ), (268, $PDU - Q^1$ ), (277, $rem1^2$ )
243	0	$K, 0$	9	$F, DA, SA, I$	(277, $rep^1$ ), (269, $PDU - Q^1$ ), (278, $rem1^2$ )
244	0	$I, K, 0$	9	$DA, SA$	(278, $rep^1$ ), (270, $PDU - Q^1$ ), (279, $rem1^2$ )
245	0	$SA, I, K, 0$	9	—	(279, $rep^1$ ), (271, $PDU - Q^1$ )
246	9	—	2	$DA, SA, I, K, 0$	(280, $yes^2$ ), (281, $no^2$ )
247	9	$F, DA$	3	$SA, I, K, 0$	(280, $rem1^1$ ), (283, $cr^2$ )
248	9	$F, DA$	0	$SA, I, K, 0$	(281, $rem1^1$ ), (283, $PDU - Q^2$ ), (284, $rep^2$ )
249	9	$J, F, DA, SA$	3	$I, K, 0$	(282, $rem1^1$ ), (285, $cr^2$ )
250	9	$J, F, DA$	5	$SA, I, K, 0$	(283, $rem1^1$ ), (286, $rep^2$ )
251	9	$J, F, DA, SA$	0	$I, K, 0$	(284, $rem1^1$ ), (286, $PDU - Q^2$ ), (287, $rep^2$ )
252	9	$F$	13	$DA, SA, I, K, 0$	(288, $rem1^1$ ), (289, $yes^2$ ), (283, $no^2$ )
253	9	$J, F, DA$	11	$SA, I, K, 0$	(289, $rem1^1$ ), (290, $cr^2$ )
254	9	$K, J, F, DA, SA$	11	$I, K, 0$	(290, $rem1^1$ ), (291, $cr^2$ )
255	9	$K, J, F, DA, SA$	5	$I, K, 0$	(286, $rem1^1$ ), (292, $rep^2$ )

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	transitions
256	9	$K, J, F, DA, SA, I$	3	$K, 0$	$(285, rem^1), (293, Ack^2)$
257	9	$K, J, F, DA, SA, I$	0	$K, 0$	$(287, rem^1)$
258	8	$K, J, F, DA, SA, I, K$	4	—	$(293, EOF^1)$
259	8	$K, J, F, DA, SA, I$	5	$K$	$(292, EOF^1), (295, rep^2)$
260	8	$K, J, F, DA, SA, I, K$	0	—	$(294, EOF^1), (295, PDU - Q^2)$
261	8	$K, J, F, DA, SA, I$	11	$K$	$(291, EOF^1), (296, K^2)$
262	5	—	9	$K, J, F, DA, SA, I, K, 1$	$(297, rem^2)$
263	15	0	9	$J, F, DA, SA, I, K$	$(297, Ack^1), (298, rem^2)$
264	14	$K, 0$	9	$F, DA, SA, I$	$(298, K^1), (299, rem^2)$
265	14	$I, K, 0$	9	$DA, SA$	$(299, cr^1), (300, rem^2)$
266	14	$SA, I, K, 0$	9	—	$(300, cr^1)$
267	5	—	9	$K, J, F, DA, SA, I, K, 0$	$(301, rem^2)$
268	5	0	9	$J, F, DA, SA, I, K$	$(301, rep^1), (302, rem^2)$
269	5	$K, 0$	9	$F, DA, SA, I$	$(302, rep^1), (303, rem^2)$
270	5	$I, K, 0$	9	$DA, SA$	$(303, rep^1), (304, rem^2)$
271	5	$SA, I, K, 0$	9	—	$(304, rep^1)$
272	0	—	9	$J, F, DA, SA, I, K, 1$	$(294, PDU - Q^1), (305, rem^2)$
273	4	0	9	$F, DA, SA, I, K$	$(305, Ack^1), (306, rem^2)$
274	3	$K, 0$	9	$DA, SA, I$	$(306, K^1), (307, rem^2)$
275	3	$I, K, 0$	9	$SA$	$(307, cr^1), (308, M, A^2)$
276	0	—	9	$J, F, DA, SA, I, K, 0$	$(301, PDU - Q^1), (309, rem^2)$
277	0	0	9	$F, DA, SA, I, K$	$(309, rep^1), (302, PDU - Q^1), (310, rem^2)$
278	0	$K, 0$	9	$DA, SA, I$	$(310, rep^1), (303, PDU - Q^1), (311, rem^2)$
279	0	$I, K, 0$	9	$SA$	$(311, rep^1), (304, PDU - Q^1), (312, M, A^2)$
280	9	$DA$	3	$SA, I, K, 0$	$(313, rem^1), (314, cr^2)$
281	9	$DA$	0	$SA, I, K, 0$	$(315, rem^1), (316, rep^2), (317, PDU - Q^2)$

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	transitions
282	9	$F, DA, SA$	3	$I, K, 0$	$(314, rem1^1), (318, cr^2)$
283	9	$F, DA$	5	$SA, I, K, 0$	$(317, rem1^1), (319, rep^2)$
284	9	$F, DA, SA$	0	$I, K, 0$	$(316, rem1^1), (320, rep^2),$ $(319, PDU - Q^2)$
285	9	$J, F, DA, SA, I$	3	$K, 0$	$(318, rem1^1), (321, K^2)$
286	9	$J, F, DA, SA$	5	$I, K, 0$	$(319, rem1^1), (322, rep^2)$
287	9	$J, F, DA, SA, I$	0	$K, 0$	$(320, rem1^1), (322, PDU - Q^2),$ $(323, rep^2)$
288	9	—	13	$DA, SA, I, K, 0$	$(324, yes^2), (317, no^2)$
289	9	$F, DA$	11	$SA, I, K, 0$	$(321, rem1^1), (325, cr^2)$
290	9	$J, F, DA, SA$	11	$I, K, 0$	$(325, rem1^1), (326, cr^2)$
291	9	$K, J, F, DA, SA, I$	11	$K, 0$	$(326, rem1^1), (327, K^2)$
292	9	$K, J, F, DA, SA, I$	5	$K, 0$	$(322, rem1^1), (328, rep^2)$
293	9	$K, J, F, DA, SA, I, K$	4	0	$(321, rem1^1), (329, Ack^2)$
294	9	$K, J, F, DA, SA, I, K$	0	0	$(323, rem1^1), (328, PDU - Q^2),$ $(330, rep^2)$
295	8	$K, J, F, DA, SA, I, K$	5	—	$(328, XEOF^1)$
296	8	$K, J, F, DA, SA, I, K$	15	—	$(327, XEOF^1)$
297	5	—	9	$J, F, DA, SA, I, K, 1$	$(331, rem1^2)$
298	15	0	9	$F, DA, SA, I, K$	$(331, Ack^1), (332, rem1^2)$
299	11	$K, 0$	9	$DA, SA, I$	$(332, K^1), (333, rem1^2)$
300	11	$I, K, 0$	9	$SA$	$(333, cr^1), (331, MA^2)$
301	5	—	9	$J, F, DA, SA, I, K, 0$	$(335, rem1^2)$
302	5	0	9	$F, DA, SA, I, K$	$(335, rep^1), (336, rem1^2)$
303	5	$K, 0$	9	$DA, SA, I$	$(336, rep^1), (337, rem1^2)$
304	5	$I, K, 0$	9	$SA$	$(337, rep^1), (338, MA^2)$
305	0	—	9	$F, DA, SA, I, K, 1$	$(331, PDU - Q^1), (339, rem1^2)$
306	4	0	9	$DA, SA, I, K$	$(339, Ack^1), (340, rem1^2)$
307	3	$K, 0$	9	$SA, I$	$(340, K^1), (341, MA^2)$
308	3	$I, K, 0$	10	—	$(341, cr^1), (342, newT^2)$

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	transitions
309	0	—	9	$F, DA, SA, I, K, 0$	$(335, PDU - Q^1), (343, rem1^2)$
310	0	0	9	$DA, SA, I, K$	$(343, rep^1), (336, PDU - Q^1), (344, rem1^2)$
311	0	$K, 0$	9	$SA, I$	$(344, rep^1), (337, PDU - Q^1), (345, MA^2)$
312	0	$I, K, 0$	10	—	$(345, rep^1), (338, PDU - Q^1), (346, newT^2)$
313	9	—	3	$SA, I, K, 0$	$(347, cr^2)$
314	9	$DA, SA$	3	$I, K, 0$	$(347, rem1^1), (348, cr^2)$
315	9	—	0	$SA, I, K, 0$	$(349, PDU - Q^2), (350, rep^2)$
316	9	$DA, SA$	0	$I, K, 0$	$(350, rem1^1), (351, PDU - Q^2), (352, rep^2)$
317	9	$DA$	5	$SA, I, K, 0$	$(349, rem1^1), (351, rep^2)$
318	9	$F, DA, SA, I$	3	$K, 0$	$(348, rem1^1), (353, K^2)$
319	9	$F, DA, SA$	5	$I, K, 0$	$(351, rem1^1), (351, rep^2)$
320	9	$F, DA, SA, I$	0	$K, 0$	$(352, rem1^1), (351, PDU - Q^2), (355, rep^2)$
321	9	$J, F, DA, SA, I, K$	4	0	$(353, rem1^1), (356, Ack^2)$
322	9	$J, F, DA, SA, I$	5	$K, 0$	$(354, rem1^1), (357, rep^2)$
323	9	$J, F, DA, SA, I, K$	0	0	$(355, rem1^1), (357, PDU - Q^2), (358, rep^2)$
324	9	$DA$	11	$SA, I, K, 0$	$(359, rem1^1), (360, cr^2)$
325	9	$F, DA, SA$	11	$I, K, 0$	$(360, rem1^1), (361, cr^2)$
326	9	$J, F, DA, SA, I$	11	$K, 0$	$(361, rem1^1), (362, K^2)$
327	9	$K, J, F, DA, SA, I, K$	15	0	$(362, rem1^1), (363, Ack^2)$
328	9	$K, J, F, DA, SA, I, K$	5	0	$(357, rem1^1), (364, rep^2)$
329	9	$K, J, F, DA, SA, I, K, 1$	0	—	$(356, rem1^1), (363, PDU - Q^2)$
330	9	$K, J, F, DA, SA, I, K, 0$	0	—	$(358, rem1^1), (364, PDU - Q^2)$
331	5	—	9	$F, DA, SA, I, K, 1$	$(365, rem1^2)$
332	15	0	9	$DA, SA, I, K$	$(365, Ack^1), (366, rem1^2)$

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	transitions
333	14	$K, 0$	9	$SA, I$	$(366, K^1), (367, MA^2)$
334	14	$I, K, 0$	10	—	$(367, cr^1), (368, newT^2)$
335	5	—	9	$F, DA, SA, I, K, 0$	$(369, rem1^2)$
336	5	0	9	$DA, SA, I, K$	$(369, rep^1), (370, rem1^2)$
337	5	$K, 0$	9	$SA, I$	$(370, rep^1), (371, MA^2)$
338	5	$I, K, 0$	10	—	$(371, rep^1), (372, newT^2)$
339	0	—	9	$DA, SA, I, K, 1$	$(365, PDU - Q^1), (373, rem1^2)$
340	4	0	9	$SA, I, K$	$(373, Ack^1), (374, MA^2)$
341	3	$K, 0$	10	$I$	$(374, K^1), (375, newT^2)$
342	3	$I, K, 0, J, T, K$	11	—	$(375, cr^1)$
343	0	—	9	$DA, SA, I, K, 0$	$(369, PDU - Q^1), (376, rem1^2)$
344	0	0	9	$SA, I, K$	$(370, PDU - Q^1), (376, rep^1), (377, MA^2)$
345	0	$K, 0$	10	$I$	$(371, PDU - Q^1), (377, rep^1), (378, newT^2)$
346	0	$I, K, 0, J, T, K$	11	—	$(372, PDU - Q^1), (378, rep^1)$
347	9	$SA$	3	$I, K, 0$	$(379, MA^1), (380, cr^2)$
348	9	$DA, SA, I$	3	$K, 0$	$(380, rem1^1), (381, K^2)$
349	9	—	5	$SA, I, K, 0$	$(382, rep^2)$
350	9	$SA$	0	$I, K, 0$	$(383, MA^1), (382, PDU - Q^2), (384, rep^2)$
351	9	$DA, SA$	5	$I, K, 0$	$(382, rem1^1), (385, rep^2)$
352	9	$DA, SA, I$	0	$K, 0$	$(384, rem1^1), (385, PDU - Q^2), (386, rep^2)$
353	9	$F, DA, SA, I, K$	1	0	$(384, rem1^1), (387, Ack^2)$
354	9	$F, DA, SA, I$	5	$K, 0$	$(385, rem1^1), (388, rep^2)$
355	9	$F, DA, SA, I, K$	0	0	$(386, rem1^1), (388, PDU - Q^2), (389, rep^2)$
356	9	$J, F, DA, SA, I, K, 1$	0	—	$(387, rem1^1), (390, PDU - Q^1)$
357	9	$J, F, DA, SA, I, K$	5	0	$(388, rem1^1), (391, rep^2)$

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	$transitions$
358	9	$J, F, DA, SA, I, K, 0$	0	—	$(389, rem1^1), (391, PDU - Q^1)$
359	9	—	11	$SA, I, K, 0$	$(392, cr^2)$
360	9	$DA, SA$	11	$I, K, 0$	$(392, rem1^1), (393, cr^2)$
361	9	$F, DA, SA, I$	11	$K, 0$	$(393, rem1^1), (394, K^2)$
362	9	$J, F, DA, SA, I, K$	15	0	$(394, rem1^1), (390, Ack^2)$
363	9	$K, J, F, DA, SA, I, K, 1$	5	—	$(390, rem1^1)$
364	9	$K, J, F, DA, SA, I, K, 0$	5	—	$(391, rem1^1)$
365	5	—	9	$DA, SA, I, K, 1$	$(395, rem1^2)$
366	15	0	9	$SA, I, K$	$(395, Ack^1), (396, MA^2)$
367	11	$K, 0$	10	$I$	$(396, K^1)$
368	11	$I, K, 0, J, T, K$	11	—	$(397, cr^1)$
369	5	—	9	$DA, SA, I, K, 0$	$(398, rem1^2)$
370	5	0	9	$SA, I, K$	$(398, rep^1), (399, MA^2)$
371	5	$K, 0$	10	$I$	$(399, rep^1), (400, newT^2)$
372	5	$I, K, 0, J, T, K$	11	—	$(400, rep^1)$
373	0	—	9	$SA, I, K, 1$	$(395, PDU - Q^1), (401, MA^2)$
374	4	0	10	$I, K$	$(401, Ack^1), (402, newT^2)$
375	3	$K, 0, J, T, K$	11	$I$	$(402, K^1), (403, rem2^2)$
376	0	—	9	$SA, I, K, 0$	$(398, PDU - Q^1), (401, MA^2)$
377	0	0	10	$I, K$	$(401, rep^1), (399, PDU - Q^1), (405, newT^2)$
378	0	$K, 0, J, T, K$	11	$I$	$(405, rep^1), (400, PDU - Q^1), (406, rem2^2)$
379	10	—	3	$I, K, 0$	$(407, newT^1), (408, cr^2)$
380	9	$SA, I$	3	$K, 0$	$(408, MA^1), (409, K^2)$
381	9	$DA, SA, I, K$	4	0	$(409, rem1^1), (410, Ack^2)$
382	9	$SA$	5	$I, K, 0$	$(411, MA^1), (412, rep^2)$
383	10	—	0	$I, K, 0$	$(413, newT^1), (411, PDU - Q^2), (411, rep^2)$
384	9	$SA, I$	0	$K, 0$	$(411, MA^1), (412, PDU - Q^2), (415, rep^2)$

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	transitions
385	9	$DA, SA, I$	5	$K, 0$	(412, $rem1^1$ ), (416, $rep^2$ )
386	9	$DA, SA, I, K$	0	0	(415, $rem1^1$ ), (416, $PDU - Q^2$ ), (417, $rep^2$ )
387	9	$F, DA, SA, I, K, 1$	0	—	(410, $rem1^1$ )
388	9	$F, DA, SA, I, K$	5	0	(416, $rem1^1$ ), (418, $rep^2$ )
389	9	$F, DA, SA, I, K, 0$	0	—	(417, $rem1^1$ ), (418, $PDU - Q^2$ )
390	9	$J, F, DA, SA, I, K, 1$	5	—	(419, $rem1^1$ )
391	9	$J, F, DA, SA, I, K, 0$	5	—	(418, $rem1^1$ )
392	9	$SA$	14	$I, K, 0$	(420, $MA^1$ ), (421, $cr^2$ )
393	9	$DA, SA, I$	11	$K, 0$	(421, $rem1^1$ ), (422, $K^2$ )
394	9	$F, DA, SA, I, K$	15	0	(422, $rem1^1$ ), (419, $Ack^2$ )
395	5	—	9	$SA, I, K, 1$	(423, $MA^2$ )
396	15	0	10	$I, K$	(423, $Ack^1$ ), (424, $newT^2$ )
397	11	$K, 0, J, I, K$	11	$I$	(424, $K^1$ ), (425, $rem2^2$ )
398	5	—	9	$SA, I, K, 0$	(426, $MA^2$ )
399	5	0	10	$I, K$	(426, $rep^1$ ), (427, $newT^2$ )
400	5	$K, 0, J, I, K$	11	$I$	(427, $rep^1$ ), (428, $rem2^2$ )
401	0	—	10	$I, K, 1$	(423, $PDU - Q^1$ ), (429, $newT^2$ )
402	1	$0, J, I, K$	11	$I, K$	(429, $Ack^1$ ), (430, $rem2^2$ )
403	3	$K, 0, J, I, K$	11	—	(430, $K^1$ )
404	0	—	10	$I, K, 0$	(426, $PDU - Q^1$ ), (431, $newT^2$ )
405	0	$0, J, I, K$	11	$I, K$	(427, $PDU - Q^1$ ), (431, $rep^1$ ), (432, $rem2^2$ )
406	0	$K, 0, J, I, K$	11	—	(428, $PDU - Q^1$ ), (432, $rep^1$ )
407	11	—	3	$I, K, 0, J, I, K$	(433, $cr^2$ )
408	10	$I$	3	$K, 0$	(433, $newT^1$ ), (434, $K^2$ )
409	9	$SA, I, K$	4	0	(434, $MA^1$ ), (435, $Ack^2$ )
410	9	$DA, SA, I, K, 1$	0	—	(435, $rem1^1$ ), (436, $PDU - Q^2$ )
411	10	—	5	$I, K, 0$	(437, $newT^1$ ), (438, $rep^2$ )
412	9	$SA, I$	5	$K, 0$	(438, $MA^1$ ), (439, $rep^2$ )

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	transitions
413	11	—	0	$I, K, 0, J, T, K$	(437, $PDU - Q^2$ ), (440, $rep^2$ )
414	10	$I$	0	$K, 0$	(440, $newT^1$ ), (438, $PDU - Q^2$ ) (441, $rep^2$ )
415	9	$SA, I, K$	0	0	(441, $MA^1$ ), (439, $PDU - Q^2$ ), (442, $rep^2$ )
416	9	$DA, SA, I, K$	5	0	(439, $rem1^1$ ), (443, $rep^2$ )
417	9	$DA, SA, I, K, 0$	0	—	(442, $rem1^1$ ), (443, $PDU - Q^2$ )
418	9	$F, DA, SA, I, K, 0$	5	—	(443, $rem1^1$ )
419	9	$F, DA, SA, I, K, 1$	5	—	(436, $rem1^1$ )
420	10	—	11	$I, K, 0$	(444, $newT^1$ ), (445, $cr^2$ )
421	9	$SA, I$	11	$K, 0$	(445, $MA^1$ ), (446, $K^2$ )
422	9	$DA, SA, I, K$	15	0	(446, $rem1^1$ ), (436, $Ack^2$ )
423	5	—	10	$I, K, 1$	(447, $newT^2$ )
424	15	$0, J, T, K$	11	$I, K$	(447, $Ack^1$ ), (448, $rem2^2$ )
425	14	$K, 0, J, T, K$	11	—	(448, $K^1$ )
426	5	—	10	$I, K, 0$	(449, $newT^2$ )
427	5	$0, J, T, K$	11	$I, K$	(449, $rep^1$ ), (450, $rem2^2$ )
428	5	$K, 0, J, T, K$	11	—	(450, $rep^1$ )
429	0	$J, T, K$	11	$I, K, 1$	(451, $J^1$ ), (447, $PDU - Q^1$ ), (452, $rem2^2$ )
430	4	$0, J, T, K$	11	$K$	(452, $Ack^1$ ), (453, $remK^2$ )
431	0	$J, T, K$	11	$I, K, 0$	(454, $J^1$ ), (449, $PDU - Q^1$ ), (455, $rem2^2$ )
432	0	$0, J, T, K$	11	$K$	(455, $rep^1$ ), (450, $PDU - Q^1$ ), (456, $remK^2$ )
433	11	$I$	3	$K, 0, J, T, K$	(457, $rem2^1$ ), (458, $K^2$ )
434	10	$I, K$	4	0	(458, $newT^1$ ), (459, $Ack^2$ )
435	9	$SA, I, K, 1$	0	—	(459, $MA^1$ ), (460, $PDU - Q^2$ )
436	9	$DA, SA, I, K, 1$	5	—	(460, $rem1^1$ )
437	11	—	5	$I, K, 0, J, T, K$	(461, $rep^2$ )

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	transitions
438	10	$I$	5	$K, 0$	(461, $newT^1$ ), (462, $rep^2$ )
439	9	$SA, I, K$	5	0	(462, $MA^1$ ), (463, $rep^2$ )
440	11	$I$	0	$K, 0, J, T, K$	(464, $rem2^1$ ), (461, $PDU - Q^2$ ), (465, $rep^2$ )
441	10	$I, K$	0	0	(465, $newT^1$ ), (462, $PDU - Q^2$ ), (466, $rep^2$ )
442	9	$SA, I, K, 0$	0	—	(466, $MA^1$ ), (463, $PDU - Q^2$ )
443	9	$DA, SA, I, K, 0$	5	—	(463, $rem1^1$ )
444	11	—	11	$I, K, 0, J, T, K$	(467, $cr^2$ )
445	10	$I$	11	$K, 0$	(467, $newT^1$ ), (468, $K^2$ )
446	9	$SA, I, K$	15	0	(468, $MA^1$ ), (460, $Ack^2$ )
447	5	$J, T, K$	11	$I, K, 1$	(469, $J^1$ ), (470, $rem2^2$ )
448	15	$0, J, T, K$	11	$K$	(470, $Ack^1$ ), (471, $remK^2$ )
449	5	$J, T, K$	11	$I, K, 0$	(472, $J^1$ ), (473, $rem2^2$ )
450	5	$0, J, T, K$	11	$K$	(473, $rep^1$ ), (474, $remK^2$ )
451	1	$T, K$	11	$I, K, 1, J$	(475, $T_1^1$ ), (476, $rem2^2$ )
452	0	$J, T, K$	11	$K, 1$	(476, $J^1$ ), (470, $PDU - Q^1$ ), (477, $remK^2$ )
453	4	$0, J, T, K$	12	—	(477, $Ack^1$ )
454	1	$T, K$	11	$I, K, 0, J$	(478, $T_1^1$ ), (479, $rem2^2$ )
455	0	$J, T, K$	11	$K, 0$	(473, $PDU - Q^1$ ), (479, $J^1$ ), (480, $remK^2$ )
456	0	$0, J, T, K$	12	—	(474, $PDU - Q^1$ ), (480, $rep^1$ )
457	11	—	3	$K, 0, J, T, K$	(481, $K^2$ )
458	11	$I, K$	1	$0, J, T, K$	(481, $rem2^1$ ), (482, $Ack^2$ )
459	10	$I, K, 1$	0	—	(482, $newT^1$ ), (483, $PDU - Q^2$ )
460	9	$SA, I, K, 1$	5	—	(483, $MA^1$ )
461	11	$I$	5	$K, 0, J, T, K$	(484, $rem2^1$ ), (485, $rep^2$ )
462	10	$I, K$	5	0	(485, $newT^1$ ), (486, $rep^2$ )
463	9	$SA, I, K, 0$	5	—	(486, $MA^1$ )

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	transitions
464	11	—	0	$K, 0, J, T, K$	(484, $PDU - Q^2$ ), (487, $rep^2$ )
465	11	$J, K$	0	$0, J, T, K$	(487, $rem2^1$ ), (485, $PDU - Q^2$ ), (488, $rep^2$ )
466	10	$J, K, 0$	0	—	(488, $newT^1$ ), (486, $PDU - Q^2$ )
467	11	$J$	14	$K, 0, J, T, K$	(489, $rem2^1$ ), (490, $K^2$ )
468	10	$J, K$	15	0	(490, $newT^1$ ), (483, $Ack^2$ )
469	6	$T, K$	11	$J, K, 1, J$	(491, $T_2^1$ )
470	5	$J, T, K$	11	$K, 1$	(492, $J^1$ ), (493, $remK^2$ )
471	15	$0, J, T, K$	12	—	(493, $Ack^1$ )
472	6	$T, K$	11	$J, K, 0, J$	(494, $T_2^1$ ), (495, $rem2^2$ )
473	5	$J, T, K$	11	$K, 0$	(495, $J^1$ ), (496, $remK^2$ )
474	5	$0, J, T, K$	12	—	(496, $rep^1$ )
475	0	$K$	11	$J, K, 1, J, T$	(497, $PDU - Q^1$ ), (498, $rep^1$ ), (499, $rem2^2$ )
476	1	$T, K$	11	$K, 1, J$	(499, $T_1^1$ ), (500, $remK^2$ )
477	0	$J, T, K$	12	1	(500, $J^1$ ), (493, $PDU - Q^1$ ), (0, $OK^2$ )
478	0	$K$	11	$J, K, 0, J, T$	(501, $PDU - Q^1$ ), (502, $rep^1$ ), (503, $rem2^1$ )
479	1	$T, K$	11	$K, 0, J$	(503, $T_1^1$ ), (504, $remK^2$ )
480	0	$J, T, K$	12	0	(504, $J^1$ ), (2, $miss^2$ )
481	11	$K$	1	$0, J, T, K$	(505, $remK^1$ ), (506, $Ack^2$ )
482	11	$J, K, 1$	0	$J, T, K$	(506, $rem2^1$ ), (507, $PDU - Q^2$ ), (508, $J^2$ )
483	10	$J, K, 1$	5	—	(507, $newT^1$ )
484	11	—	5	$K, 0, J, T, K$	(509, $rep^2$ )
485	11	$J, K$	5	$0, J, T, K$	(509, $rem2^1$ ), (510, $rep^2$ )
486	10	$J, K, 0$	5	—	(510, $newT^1$ )
487	11	$K$	0	$0, J, T, K$	(511, $remK^1$ ), (509, $PDU - Q^2$ ), (512, $rep^2$ )

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	transitions
488	11	$I, K, 0$	0	$J, T, K$	$(512, rem2^1), (510, PDU - Q^2), (513, J^2)$
489	11	—	14	$K, 0, J, T, K$	$(514, K^2)$
490	11	$I, K$	15	$0, J, T, K$	$(514, rem2^1), (507, Ack^2)$
491	7	$K$	11	$I, K, 1, J, F$	$(515, XMit^1), (516, rem2^2)$
492	6	$T, K$	11	$K, 1, J$	$(516, T_2^1), (517, remK^2)$
493	5	$J, T, K$	12	1	$(517, J^1), (1, OK^2)$
494	7	$K$	11	$I, K, 0, J, F$	$(518, XMit^1), (519, rem2^2)$
495	6	$T, K$	11	$K, 0, J$	$(519, T_2^1), (520, remK^2)$
496	5	$J, T, K$	12	0	$(520, J^1), (17, miss^2)$
497	5	$K$	11	$I, K, 1, J, T$	$(521, rep^1), (522, rem2^2)$
498	0	—	11	$I, K, 1, J, T, K$	$(521, PDU - Q^1), (523, rem2^2)$
499	0	$K$	11	$K, 1, J, T$	$(523, rep^1), (522, PDU - Q^1), (524, remK^2)$
500	1	$T, K$	12	1, $J$	$(524, T_1^1), (3, OK^2)$
501	5	$K$	11	$I, K, 0, J, T$	$(525, rep^1), (526, rem2^2)$
502	0	—	11	$I, K, 0, J, T, K$	$(525, PDU - Q^1), (527, rem2^2)$
503	0	$K$	11	$K, 0, J, T$	$(526, PDU - Q^1), (527, rep^1), (528, remK^2)$
504	1	$T, K$	12	0, $J$	$(528, T_1^1), (6, miss^2)$
505	12	—	1	$0, J, T, K$	$(529, Ack^2)$
506	11	$K, 1$	0	$J, T, K$	$(529, remK^1), (530, PDU - Q^2), (531, J^2)$
507	11	$I, K, 1$	5	$J, T, K$	$(530, rem2^1), (532, J^2)$
508	11	$I, K, 1, J$	1	$I, K$	$(531, rem2^1), (533, T_1^2)$
509	11	$K$	5	$0, J, T, K$	$(531, remK^1), (535, rep^2)$
510	11	$I, K, 0$	5	$J, T, K$	$(535, rem2^1), (536, J^2)$
511	12	—	0	$0, J, T, K$	$(534, PDU - Q^2), (537, rep^2)$
512	11	$K, 0$	0	$J, T, K$	$(537, remK^1), (535, PDU - Q^2), (538, J^2)$

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	transitions
513	11	$I, K, 0, J$	1	$T, K$	$(538, rem2^1), (539, T_1^2)$
514	11	$K$	15	$0, J, T, K$	$(540, remK^1), (540, Ack^2)$
515	7	$K$	11	$I, K, 1, J, F, DA, SA, I$	$(541, EPDU^1), (542, rem2^2)$
516	7	$K$	11	$K, 1, J, F$	$(542, XMit^1), (543, remK^2)$
517	6	$T, K$	12	$1, J$	$(543, T_2^1), (46, OK^2)$
518	7	$K$	11	$I, K, 0, J, F, DA, SA, I$	$(544, EPDU^1), (545, rem2^2)$
519	7	$K$	11	$K, 0, J, F$	$(545, XMit^1), (546, remK^2)$
520	6	$T, K$	12	$0, J$	$(546, T_2^1), (62, miss^2)$
521	5	—	11	$I, K, 1, J, T, K$	$(547, rem2^2)$
522	5	$K$	11	$K, 1, J, T$	$(547, rep^1), (548, remK^2)$
523	0	—	11	$K, 1, J, T, K$	$(547, PDU - Q^1), (549, remK^2)$
524	0	$K$	12	$1, J, T$	$(548, PDU - Q^1), (549, rep^1), (4, OK^2)$
525	5	—	11	$I, K, 0, J, T, K$	$(550, rem2^2)$
526	5	$K$	11	$K, 0, J, T$	$(550, rep^1), (551, remK^2)$
527	0	—	11	$K, 0, J, T, K$	$(550, PDU - Q^1), (552, remK^2)$
528	0	$K$	12	$0, J, T$	$(551, PDU - Q^1), (552, rep^1), (9, miss^2)$
529	12	1	0	$J, T, K$	$(7, OK^1), (553, PDU - Q^2), (554, J^2)$
530	11	$K, 1$	5	$J, T, K$	$(553, remK^1), (555, J^2)$
531	11	$K, 1, J$	1	$T, K$	$(554, remK^1), (556, T_1^2)$
532	11	$I, K, 1, J$	6	$T, K$	$(555, rem2^1), (557, T_2^2)$
533	11	$I, K, 1, J, T$	0	$K$	$(556, rem2^1), (558, PDU - Q^2), (559, rep^2)$
534	12	—	5	$0, J, T, K$	$(560, rep^1)$
535	11	$K, 0$	5	$J, T, K$	$(560, remK^1), (561, J^2)$
536	11	$I, K, 0, J$	6	$T, K$	$(561, rem2^1), (562, T_2^2)$
537	12	0	0	$J, T, K$	$(42, miss^1), (560, PDU - Q^2), (563, J^2)$

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	transitions
538	11	$K, 0, J$	1	$T, K$	$(563, remK^1), (564, T_1^2)$
539	11	$I, K, 0, J, T$	0	$K$	$(564, rem2^1), (565, PDU - Q^2), (566, rep^2)$
540	12	—	15	$0, J, T, K$	$(553, Ack^2)$
541	8	$K$	11	$I, K, 1, J, F, DA, SA, I, K$	$567, EOF^1), (568, rem2^2)$
542	7	$K$	11	$K, 1, J, F, DA, SA, I$	$(568, EPDU^1), (569, remK^2)$
543	7	$K$	12	$1, J, F$	$(569, XMit^1), (60, OK^2)$
544	8	$K$	11	$I, K, 0, J, F, DA, SA, I, K$	$(570, EOF^1), (571, rem2^2)$
545	7	$K$	11	$K, 0, J, F, DA, SA, I$	$(571, EPDU^1), (572, remK^2)$
546	7	$K$	12	$0, J, F$	$(572, XMit^1), (76, miss^2)$
547	5	—	11	$K, 1, J, F, K$	$(573, remK^2)$
548	5	$K$	12	$1, J, F$	$(573, rep^1), (8, OK^2)$
549	0	—	12	$1, J, T, K$	$(573, PDU - Q^1), (7, OK^2)$
550	5	—	11	$K, 0, J, T, K$	$(574, remK^2)$
551	5	$K$	12	$0, J, T$	$(574, rep^1), (15, miss^2)$
552	0	—	12	$0, J, T, K$	$(574, PDU - Q^1), (13, miss^2)$
553	12	1	5	$J, T, K$	$(13, OK^1), (575, J^2)$
554	12	$1, J$	1	$T, K$	$(11, OK^1), (576, T_1^2)$
555	11	$K, 1, J$	6	$T, K$	$(575, remK^1), (577, T_2^2)$
556	11	$K, 1, J, T$	0	$K$	$(576, remK^1), (578, PDU - Q^2), (579, rep^2)$
557	11	$I, K, 1, J, F$	7	$K$	$(577, rem2^1), (580, XMit^2)$
558	11	$I, K, 1, J, T$	5	$K$	$(578, rem2^1), (581, rep^2)$
559	11	$I, K, 1, J, T, K$	0	—	$(579, rem2^1), (581, PDU - Q^2)$
560	12	0	5	$J, T, K$	$(19, miss^1), (582, J^2)$
561	11	$K, 0, J$	6	$T, K$	$(582, remK^1), (583, T_2^2)$
562	11	$I, K, 0, J, F$	7	$K$	$(583, rem2^1), (584, XMit^2)$
563	12	$0, J$	1	$T, K$	$(20, miss^1), (585, T_1^2)$
564	11	$K, 0, J, T$	0	$K$	$(585, remK^1), (586, PDU - Q^2), (587, rep^2)$

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	$transitions$
565	11	$I, K, 0, J, T$	5	$K$	(586, $rem2^1$ ), (588, $rep^2$ )
566	11	$I, K, 0, J, T, K$	0	—	(587, $rem2^1$ ), (588, $PDU - Q^2$ )
567	9	$K$	11	$I, K, 1, J, F, DA, SA, I, K, 0$	(589, $rem1^1$ ), (590, $rem2^2$ )
568	8	$K$	11	$K, 1, J, F, DA, SA, I, K$	(590, $XEOF^1$ ), (591, $remK^2$ )
569	7	$K$	12	$1, J, F, DA, SA, I$	(591, $EPDU^1$ ), (71, $OK^2$ )
570	9	$K$	11	$I, K, 0, J, F, DA, SA, I, K, 0$	(592, $rem1^1$ ), (593, $rem2^2$ )
571	8	$K$	11	$K, 0, J, F, DA, SA, I, K$	(593, $XEOF^1$ ), (594, $remK^2$ )
572	7	$K$	12	$0, J, F, DA, SA, I$	(594, $EPDU^1$ ), (91, $miss^2$ )
573	5	—	12	$1, J, T, K$	(12, $OK^2$ )
574	5	—	12	$0, J, T, K$	(19, $miss^2$ )
575	12	$I, J$	6	$T, K$	(21, $OK^1$ ), (595, $T_2^2$ )
576	12	$I, J, T$	0	$K$	(23, $OK^1$ ), (596, $PDU - Q^2$ ), (597, $rep^2$ )
577	11	$K, 1, J, F$	7	$K$	(595, $remK^1$ ), (598, $XMIT^2$ )
578	11	$K, 1, J, T$	5	$K$	(596, $remK^1$ ), (599, $rep^2$ )
579	11	$K, 1, J, T, K$	0	—	(597, $remK^1$ ), (599, $PDU - Q^2$ )
580	11	$I, K, 1, J, F, DA, SA, I$	7	$K$	(600, $EPDU^2$ ), (598, $rem2^1$ )
581	11	$I, K, 1, J, T, K$	5	—	(599, $rem2^1$ )
582	12	$0, J$	6	$T, K$	(28, $miss^1$ ), (601, $T_2^2$ )
583	11	$K, 0, J, F$	7	$K$	(601, $remK^1$ ), (602, $XMIT^2$ )
584	11	$I, K, 0, J, F, DA, SA, I$	7	$K$	(602, $rem2^1$ ), (603, $EPDU^2$ )
585	12	$0, J, T$	0	$K$	(30, $miss^1$ ), (601, $PDU - Q^2$ ), (605, $rep^2$ )
586	11	$K, 0, J, T$	5	$K$	(601, $remK^1$ ), (606, $rep^2$ )
587	11	$K, 0, J, T, K$	0	—	(605, $remK^1$ ), (606, $PDU - Q^2$ )
588	11	$I, K, 0, J, T, K$	5	—	(606, $rem2^1$ )
589	9	—	11	$I, K, 1, J, F, DA, SA, I, K, 0$	(607, $rem2^2$ )
590	9	$K$	11	$K, 1, J, F, DA, SA, I, K, 0$	(607, $rem1^1$ ), (608, $remK^2$ )
591	8	$K$	12	$1, J, F, DA, SA, I, K$	(608, $XEOF^1$ ), (89, $OK^2$ )
592	9	—	11	$I, K, 0, J, F, DA, SA, I, K, 0$	(609, $rem2^2$ )

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	transitions
593	9	$K$	11	$K, 0, J, F, DA, SA, I, K, 0$	$(609, rem1^1), (610, remK^2)$
594	8	$K$	12	$0, J, F, DA, SA, I, K$	$(610, XEOF^1), (109, miss^2)$
595	12	$I, J, F$	7	$K$	$(32, OK^1), (611, XMit^2)$
596	12	$I, J, T$	5	$K$	$(34, OK^1), (612, rep^2)$
597	12	$I, J, T, K$	0	$-$	$(0, OK^1), (612, PDU - Q^2)$
598	11	$K, I, J, F, DA, SA, I$	7	$K$	$(611, remK^1), (613, EPDU^2)$
599	11	$K, I, J, T, K$	5	$-$	$(612, remK^1)$
600	11	$I, K, I, J, F, DA, SA, I, K$	8	$K$	$(613, rem2^1), (614, XEOF^2)$
601	12	$0, J, F$	7	$K$	$(10, miss^1), (615, XMit^2)$
602	11	$K, 0, J, F, DA, SA, I$	7	$K$	$(615, remK^1), (616, EPDU^2)$
603	11	$I, K, 0, J, F, DA, SA, I, K$	8	$K$	$(616, rem2^1), (617, XEOF^2)$
604	12	$0, J, T$	5	$K$	$(12, miss^1), (618, rep^2)$
605	12	$0, J, T, K$	0	$-$	$(1, miss^1), (618, PDU - Q^2)$
606	11	$K, 0, J, T, K$	5	$-$	$(618, remK^1)$
607	9	$-$	11	$K, I, J, F, DA, SA, I, K, 0$	$(619, remK^2)$
608	9	$K$	12	$I, J, F, DA, SA, I, K, 0$	$(619, rem1^1), (107, OK^2)$
609	9	$-$	11	$K, 0, J, F, DA, SA, I, K, 0$	$(620, remK^2)$
610	9	$K$	12	$0, J, F, DA, SA, I, K, 0$	$(620, rem1^1), (129, miss^2)$
611	12	$I, J, F, DA, SA, I$	7	$K$	$(41, OK^1), (621, EPDU^2)$
612	12	$I, J, T, K$	5	$-$	$(2, OK^1)$
613	11	$K, I, J, F, DA, SA, I, K$	8	$K$	$(621, remK^1), (622, XEOF^2)$
614	11	$I, K, I, J, F, DA, SA, I, K, 0$	9	$K$	$(621, rem2^1), (623, rem1^2)$
615	12	$0, J, F, DA, SA, I$	7	$K$	$(52, miss^1), (624, EPDU^2)$
616	11	$K, 0, J, F, DA, SA, I, K$	8	$K$	$(624, remK^1), (625, XEOF^2)$
617	11	$I, K, 0, J, F, DA, SA, I, K, 0$	9	$K$	$(625, rem2^1), (626, rem1^2)$
618	12	$0, J, T, K$	5	$-$	$(17, miss^1)$
619	9	$-$	12	$I, J, F, DA, SA, I, K, 0$	$(128, OK^2)$
620	9	$-$	12	$0, J, F, DA, SA, I, K, 0$	$(152, miss^2)$
621	12	$I, J, F, DA, SA, I, K$	8	$K$	$(57, OK^1), (627, XEOF^2)$
622	11	$K, I, J, F, DA, SA, I, K, 0$	9	$K$	$(627, remK^1), (628, rem1^2)$

TABLE 3: RESULTS OF THE ANALYSIS (cont)

num	$s_1$	$inbuf_1$	$s_2$	$inbuf_2$	$transitions$
623	11	$I, K, 1, J, F, DA, SA, I, K, 0$	9	—	$(628, rem2^1)$
624	12	$0, J, F, DA, SA, I, K$	8	$K$	$(67, miss^1), (629, XEOF^2)$
625	11	$K, 0, J, F, DA, SA, I, K, 0$	9	$K$	$(629, remK^1), (630, rem1^2)$
626	11	$I, K, 0, J, F, DA, SA, I, K, 0$	9	—	$(630, rem2^1)$
627	12	$I, J, F, DA, SA, I, K, 0$	9	$K$	$(72, OK^1), (631, rem1^2)$
628	11	$K, 1, J, F, DA, SA, I, K, 0$	9	—	$(631, remK^1)$
629	12	$0, J, F, DA, SA, I, K, 0$	9	$K$	$(81, miss^1), (632, rem1^2)$
630	11	$K, 0, J, F, DA, SA, I, K, 0$	9	—	$(632, remK^1)$
631	12	$I, J, F, DA, SA, I, K, 0$	9	—	$(88, OK^1)$
632	12	$0, J, F, DA, SA, I, K, 0$	9	—	$(98, miss^1)$

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